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WHAT MAKES INDUSTRIES STRATEGIC

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A popular Government, without popular information, or the means of acquiring it, is but a Prologue to a Farce or a Tragedy; or, perhaps both. Knowledge will forever govern ignorance; And a people who mean to be their own Governors, must arm themselves with the power which knowledge gives [James Madison to W.T. Barry, August 4, 1822].

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WHAT MAKES INDUSTRIES STRATEGIC

A Perspective on Technology, Economic Development, and Defense

I. TECHNOLOGY DEVELOPMENT AS STRATEGY

The Secretary of the Treasury has applied his attention to the subject of manufactures; and particularly to the means of promoting such as will tend to render the United States independent on foreign nations for military and other essential supplies.

Report on Manufactures
Alexander Hamilton
December 5, 1791

MOST PEOPLE WOULD AGREE, by instinct if not logic, that certain industries, such as computers, are more strategic than others, such as making boxes.

But what makes industries strategic? Is it size? Is it power? Is it high technology? None of these criteria truly addresses national security and well-being.

Size fails, because it begs the question of aggregation. Making fork-lifts is a minor activity and would not be strategic; but add that and a thousand similar items together, label it the engineering industry (as the British do), and suddenly it is strategic.

Power, the importance of an industry's decisions, supports the notion that a nation's own corporations should control the "commanding heights" of its economy. People who think so worry about banks, mass media, airlines, and steel industries.[1] What should really concern them is not by whom but how well decisions are made; the two are not necessarily correlated.[2]

High technology, as indicated by the ratio of research and development (R&D) to sales, tends to identify promising sectors, but for the wrong reasons. It focuses on the cost of providing technology rather than on the technology itself. Many sectors, particularly defense and pharmaceuticals, absorb considerable R&D but do little for the rest of the economy. Others, like consumer electronics, generate large numbers of low-wage jobs such as assembly, which even the Japanese have relegated to third-world countries.

We shall instead work with a more fundamental concept of what makes an industry strategic: strategic industries are those that best foster the systematic application of knowledge to generate more and better outputs from inputs. The concept covers increased productivity, the creation of better products, the better match of products and services with wants and needs, improvements in the efficacy of public goods, or increased deterrent power of the military.

The key concept here is "systematic." What matters is activities where knowledge grows to enable producers to solve problems better today than yesterday (or to solve problems better tomorrow, as with agriculture leading to biotechnology). Technological development, as such, is a matter of finding that growth path and ascending it. The argument is that certain industries promote this growth path better than others. The corollary, and in many ways more critical, argument is that such growth paths are functions not of individuals or even corporations but of the network of individuals and corporations that constitutes an economy.

Strategic industries can be understood at three levels. At one level, industries are differentially predisposed to be strategic because of their technology, structure, and markets. At another, their behavior allows them to rise beyond or fall short of their predispositions. Whether or not ceramics is a growth industry, producers who can spin off new activities (e.g., fiber optics) and support the growth of customer technologies (e.g., superconductors) or supplier technologies (e.g., autoclaving) may be very strategic indeed. At a third level, the behavior of industries may be made more or less strategic by appropriate public policies, such as technological support, public acquisition, and standards setting, or by Government's playing a role of catalyst or broker for structural transformations.

America in the World Economy. The impetus for considering a strategic perspective on industry is precisely the problematic nature of the American techno-economy in comparison with those of its competitors. With the world's best universities and most vital scientific establishment, America remains preeminent in giving birth to technological concepts. But it is falling behind in developing and applying them. Products used to be invented in Britain (e.g., penicillin or radar) but commercialized here. Today's new products are more likely to be invented here (e.g., VCRs and composites) and brought to market by Japan.

Danger signals abound.[3] A declining share, now near half, of America's patents are won by its own companies.[4] Our world share of most technology markets, particularly electronics, has dropped sharply over the decade.[5]

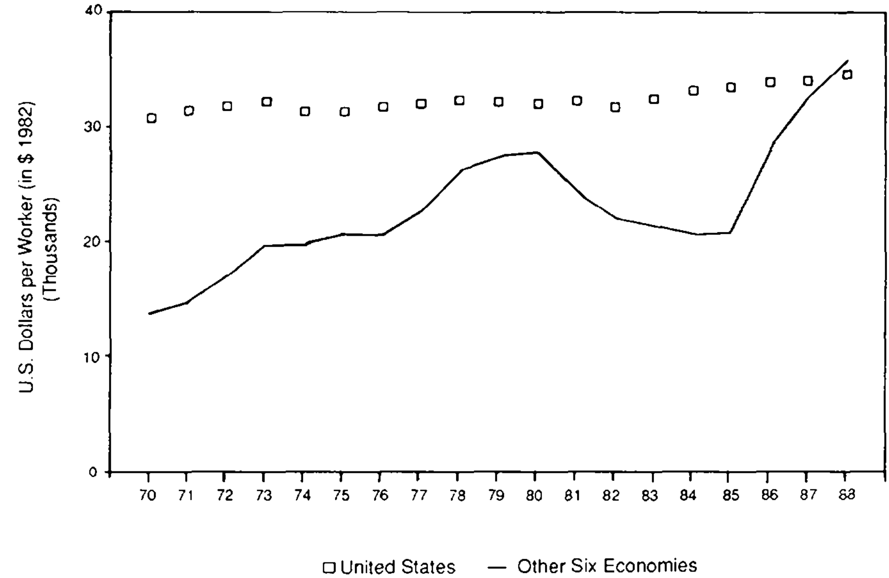
The trade deficit still runs $10 billion a month, 4 years after the dollar peaked and 2 years after it leveled out. Fred Bergsten argues, "No respectable analysis shows the current account deficit, given present policies and exchange rates, ever falling much below $100 billion."[6] A 50 percent decline in the dollar-yen ratio raised exports to Japan by 60 percent in 3 years; meanwhile, exports from Europe to Japan rose 80 percent in less time with only a 17 percent devaluation.[7]

In 1988, America's dollar GNP per employee fell below the average of the next six largest market economies for the first time in this century (chart 1). As late as 1971, it was more than twice as high. The oft-cited recovery of manufacturing productivity in the 1980's disappears if the computer industry (represented by Strategic Industrial Classification [SIC] 35) is set aside as a special case (chart 2).

Even in military technology, the trends are discouraging. Dependence on foreign sources, by all accounts, is on the rise. America's trade balance with Europe in military goods has dropped an order of magnitude to 1.6:1 despite our clear economies of scale in producing defense equipment.[8] DOD's own indicators tend to show Soviet military technology catching up with ours (table 1), with submarines, armor, and aeronautics of particular concern.[9]

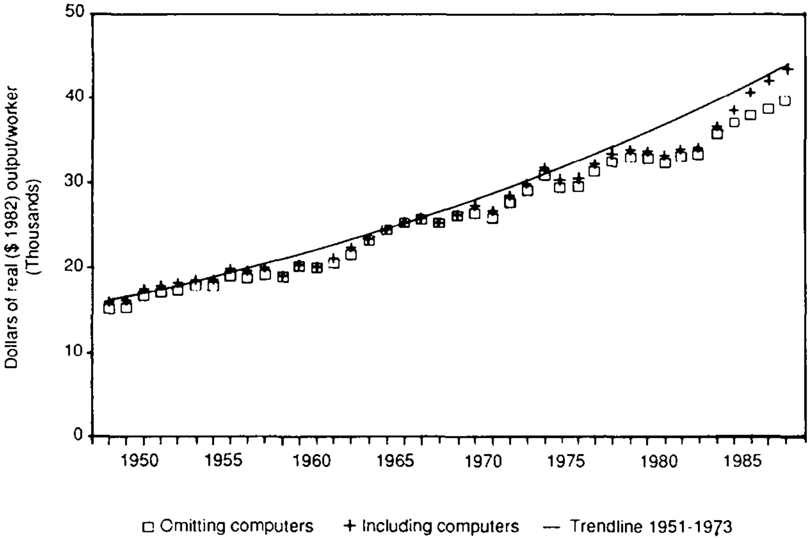
Those who believe America has serious problems nevertheless disagree on the content of—and even the need for—an industrial strategy. No one disputes that many of the causes and cures of lagging competitiveness are macro in nature. Poor schools or low savings rates affect the ability to compete and are largely independent of what industries America happens to be engaged in.

Is anything to be gained by working on America's standing in specific industries? Some say no. Fix the schools, rebuild



Source: Organization for Economic Cooperation and Development. The other six economies are Japan, Germany, France, Britain, Italy, and Canada. Data represent nominal GNP multiplied by their respective exchange rates,[10] summed together, and then divided by the number of workers in these six countries.

Chart 1. Real GNP per worker (United States vs. other six economies)



Source: Bureau of Economic Analysis, National Income and Product Accounts. Data represent real manufacturing value added divided by full-time equivalent employees (with and without SIC 35, which contains computers).

Chart 2. Productivity in manufacturing (with and without computers)

System	U.S. Ahead	Equality	U.S.S.R. Ahead
Strategic			
ICBMs		●	
Ballistic missile submarine	●		
SLBMs	▶		
Bombers	●		
Strategic SAMs			●
ASAT weapons			●
Cruise missiles		◀	
Tactical			
Tactical SAMs		▶	
Tanks		▶	
Artillery		●	
Infantry combat vehicles		●	
Antitank guided missiles		▶	
Attack helicopters	▶		
Chemical warfare			●
Biological warfare			●
Air force fighter/attack AC	▶		
Air-to-air missiles	▶		
Air-to-surface missiles	▶		
Airlift aircraft	▶		
Nuclear submarines	▶		
Torpedoes		●	
Sea-based aircraft	●		
Surface combatants	▶		
Naval cruise missiles		▶	
Mines			●
Communications		●	
Electronic countermeasures	▶		
Early warning systems	●		
Surveillance/recon systems	▶		
Training simulators	●		

▶ tending toward Soviet advantage.
◀ tending toward U.S. advantage.
● equal or clearly ahead.

Table 1. Relative strength of U.S. and Soviet military technology

the American family, balance the budget, encourage savings and investment, build more roads and airports—take your pick—and the problems of competitiveness will be solved. An economy's composition reflects its underlying attributes of education and capital. Concentrating on this or that industry, corporation, or technology can only hurt.

The opposite belief—that composition matters—does not preclude macro policies or lessen their importance. But it does ascribe importance to the competitiveness of specific industries and argues that policies should be judged, if not crafted, with that in mind.

Industrial strategy does not necessarily mean more intervention. Sometimes it means doing less (e.g., removing barriers in Government contracting). Sometimes it means doing in a different manner what one would do anyway (e.g., research and development funding). Sometimes it means emphasizing one aspect of broader policy over another (for example, market-oriented, sector-specific trade negotiations).

DOD, of course, cannot affect a stance of neutrality among technologies and industries. Its job requires that it support specific missions with specific technologies embedded in specific systems made by specific industries.

The question is not whether America can get by in this world without manufacturing. At some point, America will not be able to pay for Toyotas by selling off pieces of downtown Los Angeles. When accounts get squared, it will be mostly with goods. Making them may account for a smaller percentage of the GNP, but they still dominate world trade. They will continue to do so as long as the services' share of world trade grows only a half percent a year (as it has since 1970).[11] Moreover, America's imports of services are almost as large as its exports, many of which depend on what it knows from making things.

These trends have prompted not a systematic reaction but a parade of annual technology heroes. In 1987, fearing extinction, the semiconductor industry persuaded Congress to fund Sematech, a research consortium of key producers. In 1988, anxiety over missing out in superconductivity spurred the formation of consortia, initiatives, and commissions. The issue in 1989 is whether America must make high-definition televisions in order to protect its overall position in electronics. The process by which heroes are created and sent to battle appears to be very ad hoc, redolent of the synthetic fuels industry about 10 years ago. There is a sense in which "hysteria [over such technologies] is a symbol of what is wrong with U.S. competitiveness."[12] Which is to say, America has no industrial strategy whatsoever.

A Network Metaphor. The improvement of individuals is understandably necessary to economic development, but is it sufficient? Problem-solving processes transcend the individual and require a network of individuals, work teams, facilities, corporations, and governments. Figure 1 delineates a hypothetical but not atypical network. Much of the usefulness, the relevance, and the incentives for learning cannot be expected to thrive without such a network.

Were networks of opportunity truly international (as they are, for instance, in mathematics research), then their geography and thus, correlation with public policy, would not matter. Networks tend to clump, though. Some of them are tied to language, culture, or government (e.g., defense technology). Others are tied to institutions that rely on face-to-face contact (e.g., Wall Street or Silicon Valley). Still others are bound to corporations whose complete internationalization is well into the future (e.g., Japanese industrial groupings known as *Keiretsu*). An individual's access to growth is influenced by access to the networks of opportunity. So, by extension, are America's growth prospects.

A primary characteristic of such networks is the exchange of information leading to the solution of problems. Insofar as solving problems at one level improves problem-solving abilities at the next, being in the right place in such networks has cumulative implications. Strategic industries, we argue, are those that generate interesting problems—problems whose answers are tangible, systematic, generalizable, and sufficiently well rewarded.

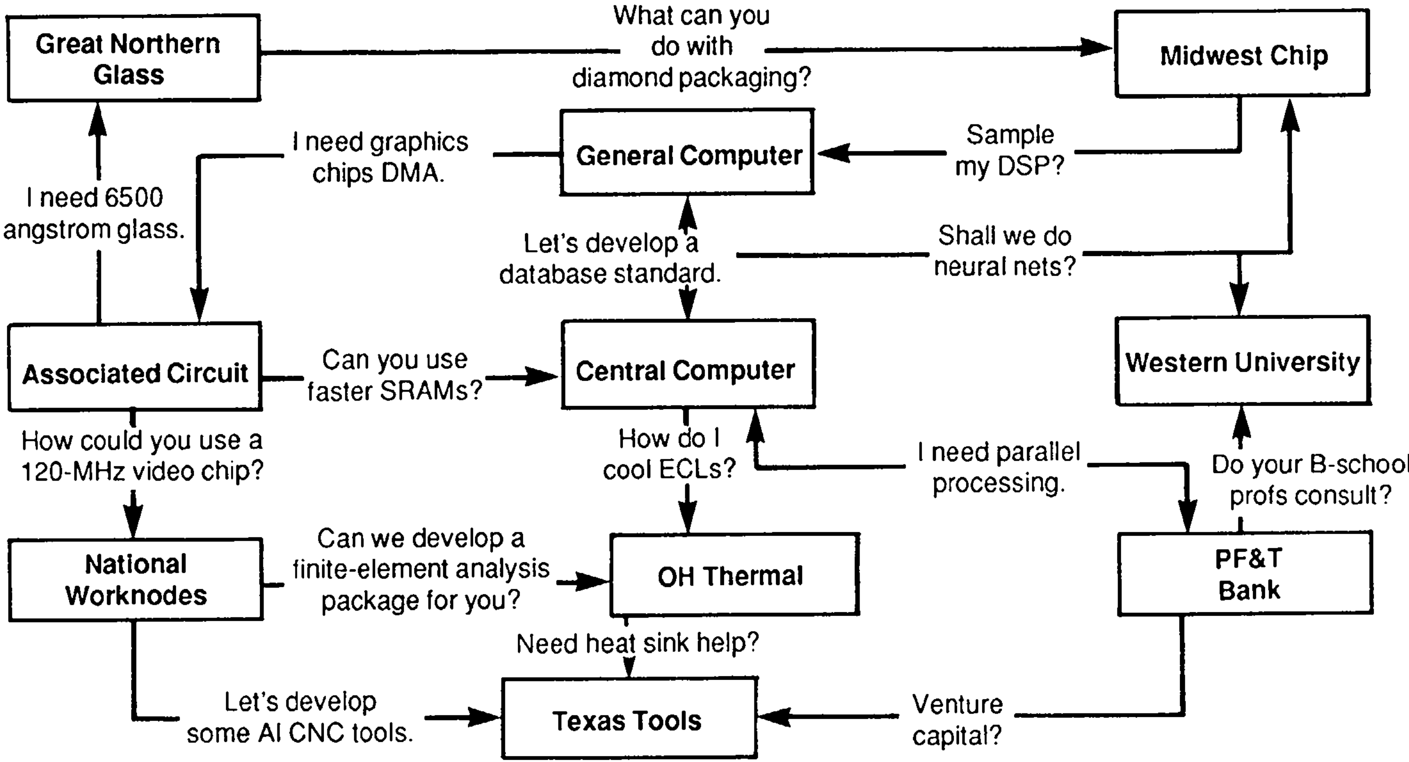


Figure 1. Networks of opportunity

An earlier work, by Cohen and Zysman,[13] explored this metaphor by arguing that a decline of manufacturing presages a decline in associated high-wage services and emphasizing "the links that promote ongoing market adaptation and technological innovation." Such links, in their view, mean that advantage in a national economy is embodied not simply in the capacities of individual firms but in the web of interconnections that establishes possibilities for all. Further, since "making links within the national economy creates real advantages and speeds the development of the most advanced technologies and the applications of these new possibilities [even] to traditional industries," strategic industries are those whose "products and processes alter or transform the goods and production arrangements throughout the economy, that is they alter the choices open to firms and the very nature and definition of the markets."

It is important, they add, for countries to ensure that their industries are players when markets shift from the fluid structures that characterize development to frozen ones that signify maturation. Granting the difficulties of identifying either stage, early technological decisions carry more weight because they shape future technological search paths.

But that still leaves the problem of defining strategic content. The decline of integrating industries (e.g., British automaking) correlates to the later decline of component manufacturing (e.g., steel and glass).[14] But the best examples of transformative industries are those that make components, whose fate less clearly presages that of integrating industries.

This paper carries on Cohen and Zysman's argument by characterizing the flow along networks of activities and showing how it fosters development. It also gauges the potential impact of DOD and the putative impact of multinationalization on this network, and uses this perspective to assess industries and policies.

II. TECHNOLOGICAL DEPENDENCE

Every nation with a view to those great objects ought to endeavor to possess within itself all the essentials of national supply. These comprise the means of subsistence, habitation, clothing and defense.

Report on Manufactures
Alexander Hamilton
December 5, 1791

AN INDUSTRY MAY BE DESCRIBED as strategic to the extent that nations are better off when they have a strong global position in that industry. How, for instance, are customers more or less advantaged by the presence of strategic industries? What about vendors and systems integrators who depend on certain industries for support in world markets? For the first question, we can examine DOD and its requirements for defense-strategic sectors; for the second, we can examine the potential problems of the American supercomputer, television, and superconductivity industries in their struggle for world markets.

What Makes Industries Strategic to Defense? What kind of defense industries does a country need in order to have a national defense? The answer is context-dependent. If in war, products from other countries are unavailable, then all industries that support defense may be considered strategic. Should DOD, then, protect every industry? Not necessarily. Most of America's industrial competition comes from allies, and only under extreme conditions would their output be unavailable. Moreover, while foreign dependence in defense procurement has its risks, such risks can be lessened by stockpiling current imports. A National Defense University (NDU) study of precision-guided munitions (PGMs) calculated that a $15 million inventory of piece-parts would allow current delivery schedules ($6 billion a year) to be met regardless of overseas disruptions.[15]

A better question is how DOD's ability to buy defense goods is complicated if key industries that supply them are dominated by imports. Can DOD rely on the same access to overseas technology that it enjoys at home? Assume, for example, that in 1992 the best semiconductor technology can only be found abroad.[16] How would that affect DOD's ability to do its job?

The answer, we argue, has three parts. Foreign firms are generally less willing than domestic firms to adapt their technology to American defense requirements. DOD will get products later if they come from overseas. Security risks will increase.

Would overseas sources be as likely as American sources to look for military applications of their technology? Defense goods, for instance, need to be insensitive to environmental stress, temperature variation, and radiation. Since maximum uptime in emergencies is vital, future electronics should be capable of testing and reconfiguring themselves on the fly. Such characteristics cost more, but in defense they are worth it.

Overseas chipmakers, though, have other criteria to guide their research. Their products work in more benign environments. Customers like quality, but they rarely have multimillion-dollar systems that turn instantly worthless in the face of unexpected faults. Consider bubble memories, environmentally hard offline storage devices, or gallium arsenide (GaAs), an alternative electronic material. Domestic firms had oriented their research toward increasing the production yield of devices that can operate with low power and at military temperatures. Japanese firms were more interested in commercial applications such as higher data-transfer rates.[17] Moreover, Japan's orientation toward high-volume commercial applications creates a reluctance to invest in low-volume equipment, production technology, or product accounting systems. Technology not produced by a domestic source is apt to be developed in ways that the military cannot use.

With technology's leading edge offshore, DOD would also have a harder time predicting the availability of technological improvements and thus what military requirements should be specified in systems.[18] Difficulties in accessing overseas technology also arise from geography and from language barriers. If the leading edge moves offshore, formal, informal, and third-party interactions between chipmakers and their users would be less frequent with longer turnarounds. Over time a growing percentage of Japanese technical publications has not been available in English. Employees at Convex, a mini-supercomputer maker, had to learn the Japanese alphabet before they realized the opportunity to use Fujitsu's gate arrays for their central logic chip.[19]

Perhaps the project manager also needs embedded software written for the system. Japanese practices differ from American ones. MITI, Japan's industrial strategist, is actively exploring the artificial intelligence uses of Prolog in its fifth-generation computer project. DOD's orientation is toward a different artificial intelligence language, LISP. With their different orientations, would Japanese firms have been as eager as Texas Instruments (TI) was to develop a LISP chip for DOD?[20]

Even where defense systems can use off-the-shelf components, there may still be a long delay in getting the best technology from abroad. Domestic customers of U.S. firms (e.g., Compaq) are often allowed to sample domestic chips (e.g., Intel's 80486) before they hit the market. By contrast, Japan's electronics houses, which account for the bulk of its chip production, may prefer to keep chips off the market so that their value can be leveraged into a competitive edge for downstream products. Only after the technology matured would they be released to market.

How long would this delay be? A Cray computer executive estimated that there was a 6-month lag in getting chips into American supercomputers; others put it at a year or two. The Office of Technology Assessment (OTA) found that some U.S. manufacturers believe that foreign suppliers of machine tools and computer parts sell U.S. companies products employing technology that is 2 to 3 years behind that of the products they sell their domestic customers.[21] The director of a recent machine-tool study at General Motors observed, "If you buy the very best from Japan, it has already been in Toyota for 2 years, and if you buy from West Germany, it has already been with BMW for a year and a half."[22] An Advanced Micro Devices (AMD) official observed that they were going to get leading-edge semiconductor manufacturing equipment later than comparable Japanese customers did, and some types they would not get at all.[23] By one account, domestic firms were receiving their dynamic random-access memory (DRAM) allocations only in dual-inline packages; Japanese customers had greater access to the more advanced, surface-mounted versions.[24]

Defense buyers may also face more subtle obstacles to full access. Japanese firms, for instance, avoid working directly with U.S. military houses unless they can claim that their contributions also have civilian uses. Such reluctance stems from interpretations of Japanese government policy against overseas military sales. Despite continuing negotiations over technology transfer, this attitude will be slow to fade. Conversely, Japanese firms may regard DOD as America's MITI. Japanese GaAs producers are reportedly reluctant to work on the Strategic Defense Initiative (SDI) for fear that American firms will learn their technology.

Can users also count on getting chips regardless of any conflicting pressures on vendors? At home, DOD is entitled by the Defense Production Act to compel on-time deliveries of items regardless of commercial demands. No such powers are available overseas. Similarly, would overseas suppliers be as willing to disrupt their other work to generate applications or solve problems in an emergency? If supplies get tight (DRAMs in 1988), lead times for chips would swell and U.S. customers would be likely to feel it worst (as did Japanese customers in getting American-made microprocessors in 1984 and 1988).

There is also security to worry about. Defense houses may have to work closely with Japanese producers to develop designs. DOD has many programs that it would hesitate to expose to foreign firms. With chips, the problem is exacerbated whenever system technologies can be read from microcircuit designs. Even with less sensitive programs, classified semiconductor devices made overseas could fall into Soviet hands. America's allies have a good record of guarding military technology themselves. Many of their firms (e.g., Toshiba, Imhausen, Kongsberg) do not.

The potential intervention of foreign governments also creates risk. Even allied states may be inhibited from supplying parts for controversial defense systems. During the Vietnam War, Sony supposedly refused to accept orders for TV cameras to go on missiles. The Japanese Diet recently debated whether Kyocera should supply ceramic semiconductor packages for cruise missiles.[25] In some cases, allies will want to keep technologies to themselves or use the threat of doing so to gain access to technologies that DOD is reluctant to release to them.

In sum, if a technology develops swiftly, if the users need the sort of information generated by familiarity to employ it well, and if such information diffuses slowly across national boundaries, then DOD stands to lose more when it has to depend on overseas sources for its best technology.

A low-information sector such as basic steel may, by such criteria, be less strategic than a high-information but otherwise similar sector such as specialty steel. The parameters of basic steel change slowly from year to year; users are familiar with its performance and need little new information on it. Specialty steelmakers continue to develop new products. Access to information on their subtle technical characteristics is important to using them well.

How Structure Affects Opportunity. The risk of losing the leading edge overseas is compounded whenever losing control over components leads to loss of the leading edge in specific systems: supercomputers, avionics, telecommunications, or solid-state radars. Supercomputers, critical to intelligence tasks and central to the computing efforts of the Defense Advanced Research Projects Agency (DARPA) and the Japanese fifth-generation project, are particularly sensitive. Even the French have subsidized efforts to gain national independence in this area.[26]

At present, Cray has two-thirds of the world market in superconductors. Its main competition comes from three Japanese electronics houses, Hitachi, NEC, and Fujitsu, which collectively hold 80 percent of their home market but have yet to export many machines.[27] Not coincidentally, the three are also semiconductor powerhouses.

Supercomputer performance depends on two types of chips: memory and processing. Cray's newest computer contains 61,000 memory chips, all built by Japanese electronics giants, some of which have been suspected of keeping their best chips at home to gain an edge in this market.[28] With processing chips, speed is what counts. Japan already claims the world's fastest single-processor machines because of its semiconductor technology.[29] For the next generation, a leading technology of choicc is the high-electron mobility transistor (HEMT), a form of GaAs around which Japan's $200 million supercomputer project is being built.[30] One Japanese laboratory director has stated that his firm intends to reserve such devices for its own machines because of their superior price-performance characteristics.[31] In a related area, more than one product development stalled when the Japanese refused to sell their newest chips to Siemens as both they and the German firm raced to develop competing telecommunications projects.[32]

Chips alone are unlikely to make or break the supercomputer market. Innovative strategies still matter. IBM added vector processing to its 9300 series mainframes to give them supercomputer capabilities, and then funded Dr. Stephen Chen from Cray to develop a true supercomputer. The United States still leads in mini-supercomputers (which offer roughly one-third the performance for one-tenth the price), parallel-processing machines, and neural-net computer research. The Japanese appear ahead in logical-inference hardware and photonic devices.

Many of the same lessons can be extended to potential manufacturers of high-definition television (HDTV) sets who would compete with the Japanese. Even if our technology, work force, capital structure, and government support were as formidable as theirs, the field would be tilted toward Japan.

Why? To compete, it helps to have many paths from factory to living room. Those like the Europeans who would sell HDTV solely on its picture quality face an uphill battle.[33] HDTV sales require the availability of software such as programs and media. Software development will be slow until there is a hardware base to run it. Given large inventories of low-definition TV equipment and media, HDTV will come to market more easily if it is compatible with what is already there. Because HDTV puts its best face forward on monster screens, and needs lots of memory for special features such as freeze-frame or split-screen, it helps if such sets are flat and smart.[34]

One path couples a high-definition display with a high-definition video-cassette recorder (VCR). Releasing movies on high-definition media could create a market for viewers that, by reaching critical mass, would make TV broadcasts with high-definition signals worthwhile. Another path starts out with a large flat-panel display and adds attributes such as high-definition. A third path allows HDTV to carry existing low-definition signals and concentrates on selling high-definition production equipment.

It is the lack of a complete production infrastructure here which closes off many paths. Japanese competitors own most of the world's commercial flat-panel display market and the leading edge of the VCR markets, and have a strong desire for the HDTV business. Each HDTV unit is estimated to need 8 megabytes of dynamic video memory. Even if Japanese competitors do not make chips themselves, they will be likely to play with the newest generation of chips first and will probably be allowed to buy them earlier.

There may still be some niches to play in. Burr-Brown is the leading supplier of digital-to-analog chips used in compact disc players,[35] Rockwell's modems are at the heart of most Japanese facsimile machines,[36] and National's graphic conversion chips are essential to Canon's laser printer engines.[37] But breaking into the web of alliances that characterizes Japanese electronics is no easy task. Most major Japanese firms feel they have to control their parts manufacturing to remain competitive.[38]

Potential vendors of components and materials such as high-temperature superconducting ceramics face similar hurdles. Their most likely customers—producers of micro-generators, magnetic levitation trains, and Josephson junction computers,[39] or even toys[40]—are in industries dominated by Japanese. Their Japanese competition would, in all likelihood, be asked to develop superconductors for Japanese customers, so that their work is more likely to be supported by loaned technology, resources, and inside information on the configurations of the systems that can use superconductors. An American device has to satisfy their needs much better than a domestic one if it is to sell into the Japanese market, and it has to overcome inherent disadvantages in ceramics infrastructure, materials-control machinery, and engineer base. Perhaps military applications of such a device can cover the American industry's research costs. The business may survive, but will see volume production only if it commercializes the results of military contracts—something that DOD all too frequently discourages.

As rational business entities, American firms would more likely forgo research in both HDTV and superconductivity and play, if at all, as resellers of Japanese goods or niche suppliers. It is not so much that they fail to bring the right stuff to the table as that they lack an industrial infrastructure to support them.

III. NETWORKS OF DEVELOPMENT

> One [objection to encouragement of manufactures is] that industry, if left to itself, will naturally find its way to the most useful and profitable employment. . . . Without the aid of government [it] will grow up as soon and as fast as the natural state of things and the interest of the community may require. Against the solidity of this hypothesis [we recognize] the intrinsic difficulties incident to first essays towards a competition with those who have previously attained to perfection in the business to be attempted, and the bounties, premiums and other artificial encouragements with which foreign nations second the exertions of their own citizens in the branches, in which they are to be rivalled.
>
> *Report on Manufactures*
> Alexander Hamilton
> December 5, 1791

ECONOMIES SURVIVE IN NATIONAL and world trade only if they can transform inputs into their particular outputs better than others. How well they do so is strongly affected by bents and abilities, both of which start from human and physical capital. But without access to a vital network of strategic industries, we argue, there are limits to their development.

The Paradox of Specialization. All economies that engage in trade inevitably specialize in certain industries. Specialization, in turn, creates differential opportunities for development. Ricardo's comparative advantage argument held that bilateral trade would benefit both England with its textiles and Portugal with its cork. Each could more cheaply trade for the other's specialty than make it itself. This mutual static optimality, though, overlooked the fact that textiles were a better area for investment. Textiles markets grew faster, their technology improved faster, and their infrastructure learned faster than the cork industry's did. Dynamic optimality favored textiles in ways that static optimality did not.

If nations could choose to specialize in certain industries, when should they target? The broadest measure of success for specialization, and hence trade, is the ability of a unit of input to buy a large and growing amount of output from others. Countries successful by that measure have appreciating currencies, reflecting increasing net exports relative to currency values at purchasing power parity.[41] A positive trade balance need not always translate into a higher currency right away; it may be used to accumulate assets. Regardless, it is a prerequisite to such choice.

The Ministry of International Trade and Industry (MITI), Japan's industrial strategist, first sought advantage by promoting industries that could demonstrate economies of scale, growth potential, high income and price elasticities, and export potential.[42] Such thinking was subsequently adopted by many newly industrialized countries (NICs) and, to some extent, by the Europeans.

Trade patterns have validated these criteria. Japan, having dominated markets for high-end electronics, precision machinery, high-purity materials, and optics, could absorb a higher yen and be in a position to raise prices without losing markets.[43] With Korea and other NICs crowding the low end of the electronics and machinery markets, Japan is taking its technology upscale; its consumer electronics companies are shifting to office and factory markets in competition with American firms.[44] The Japanese are also limiting the technology they will transfer to Koreans as potential competitors,[45] having refused to sell them technology to make VCR heads, fly-back TV transformers, autofocus camera lenses, and carbon fibers for sporting goods.[46]

Europe illustrates the advantages of being able to develop premium and branded products, which, though not growth products as such, are relatively immune to low-wage competition and can support strong currencies. Exports of engineering equipment from West Germany, Sweden, and Switzerland have proven relatively impervious to the effects of expensive currencies.[47]

The success of the newly industrialized countries illustrates the value of using simpler industries to learn more rewarding ones. More and more standardized production techniques can be duplicated around the world. A first-world economy without specialties cannot compete against the NICs, over the long run, at first-world wage rates.

The economies of American metroplexes (metropolitan complexes) exhibit similar principles. San Francisco, Boston, and Los Angeles enjoy relatively high earnings. Each of their economies is concentrated in activities that develop rapidly and reinforce each other. Regions such as Detroit and Pittsburgh that have not done as well are, among other things, concentrated in less robust sectors.

Taking these lessons together, an economy that can maintain its share of a market in an expanding industry will expand faster than one which maintains its share of a declining industry. Sectors whose skills cannot be transferred to third-world countries can survive longer and support premium earnings better. No American company can go head to head with NIC producers unless it is either much more efficient or, more likely, offers goods of superior quality, invention, or specificity. Conversely, activities that reward accreted experience can shield an economy from upstarts. This does not mean that nations should specialize in industries without entrepreneurs. An economy's competitive advantage can be located not within a corporation but in a network of activities that gives its participants larger and growing advantages over competitors. This network can then nurture start-ups without yielding to overseas entrants.

None of these advantages is guaranteed to be permanent. Markets grow and then become saturated. Information that is at one point privileged, and hence a source of competitive advantage, later becomes common knowledge. Technologies change and thus alter the terms of trade among industries. Beyond such temporary advantages there may be broader indicators of an industry's developmental potential: its ability to influence the product and production technology of other industries, create possibilities elsewhere, and avoid foreign source dependence.[48] An industry's ability to meet these criteria, in turn, is a function of its ability to develop and make use of something that can be labeled network capital.

Network Capital. It is axiomatic that an economy cannot grow without physical investment (physical capital) and a continually better educated work force (human capital). But, increasingly, the two must be supplemented by a third form of capital, to which strategic industries contribute substantially: network capital. It is composed of a knowledge of products, processes, and markets that exist outside the control of specific individuals and firms, but in the collective relationships among them. Just as the industrial revolution introduced activities too complex to be done by one or two people, the information revolution introduces activities too complex to be done solely by one or two organizations.

Network capital, like the other two kinds, is built by investing in activities such as R&D, learning-curve production experience, applications, and a network of relationships. All are prerequisites to success in knowledge-intensive sectors. A better mousetrap no longer suffices if there is no understood link between one's trap and another's mouse. This works both ways. Unguided search is both difficult and inefficient. Good answers require good questions. The latter do not arise in a vacuum but from detailed knowledge of problems and opportunities. In contrast, Europe's inability to develop innovative start-ups, by one report, results not from its lack of venture capital (now two-thirds that of America and growing) but its lack of detailed market advice and markets where innovations can be sold.[49]

The importance of questions as much as answers in developing successful industry technology is akin to the way engineering students learn by solving problems, each somewhat more difficult than the last. Interesting problems are those one learns from and is rewarded for taking on; solving them confers persisting advantages and the inside track for the next set of problems. They are manageable and fruitful. The best ones come from customers who understand the importance of their own long-term needs and will support research, development, and early production to solve them.

The purpose of such interaction at the metroplex or national level is to create a community that can solve particular problems better than its competition can. Manufacturers, in particular, are discovering that success requires more than just a well-tuned factory. Indeed, the ultimate lights-out factory creates nonroutinized problems—repair, logistics, and, most important, the ability to adapt rapidly to an ever more volatile market. Similar phenomena govern military competition—the ability to respond to a changing threat faster than the threat can react. All this takes a high degree of problem-solving skills and a network that supports mutual learning. The nodes of such a network are enhanced through their links, close examination of which speaks directly back to their strategic content.

Developmental Linkages. In developmental economics, a link is a flow of business between two nodes (e.g., industries, companies, places). Although two activities so linked will have correlated fates, it would be erroneous to conclude that linkages, per se, make sectors strategic.[50] What matters more is how developmental the linkage is in terms of the tendency of one node to learn from another as a result of its business flow. For a metroplex or nation, it is also important to understand the extent to which such linkages are more likely to be formed at close rather than far range.

Linkages used to correlate geographically because of shipping costs. Proximity of steel suppliers aided car manufacturing. These days, not only do cars use less steel but transportation costs matter less. The ton of steel in a standard American car costs no more than $80, including tariffs,[51] to haul across the ocean—much less than 1 percent of the car's cost.

Linkages now correlate geographically because of the cost of moving certain types of information in the absence of direct contact. To build a better computer faster, a maker needs to know the performance, parameters, and software of its embedded chips. The printed material is available worldwide, at once. But what is not printed exists only as practice or understanding and is disseminated through contacts arising largely through business relationships.

Linkage yields a new appreciation of the metroplex as a basis of a nation's economic organization. The fact that industries clump together—Silicon Valley or greater Boston for electronics, Ottawa for telecommunications equipment, and greater Los Angeles for aerospace—suggests that certain industries perceive differential benefits to their competitiveness from local networks of opportunity. Proximity allows informal ideas to be exchanged easily even in an age when volumes of data can be shipped anywhere cheaply. It facilitates face-to-face contact, a still inescapable part of business.

Proximity also supports the deepening of certain services, both private (e.g., computer programming) and public (e.g., education).

Sharing a common nationality adds more reasons for linkage. Common languages and social customs play a role. So do working relationships formed back when transportation was more expensive and crossing borders more difficult. Many activities are so shaped by law and regulation that experience in one country (in, say, health care or insurance) is difficult to translate into competitive position in another. Others depend directly or indirectly on government patronage (defense), regulation (telecommunications), or subsidy (research and development). Foreign steel sectors, for instance, are so dominated by their governments that American firms and their suppliers are linked by exclusion from these markets.

Developmental linkages, pushed enough, can lead an entire economy to move forward. A manufacturer, for instance, seeking to build a high-speed computer, shops for a cooling system. The manufacturer's problem becomes someone's opportunity. If developed, the superior cooling system may make very high-speed tape drives possible. Tape drives, in turn, work better with precision ceramic bearings, whose production requires computer-controlled milling machines and the education of computer-sophisticated machinists. The creation or expansion of training services allows a region to serve machine software needs more competitively. This attracts factory automation companies, and so on.

The ties between Compaq, Intel, and Microsoft illustrate the mutual value of linkages from another angle. Compaq was able to launch its newest 32-bit IBM-compatible machine even before IBM did. Intel, which made Compaq's 32-bit microprocessor, wanted to get to market as quickly as possible. Compaq had a reputation as a fast computer designer. The two worked together to correct hundreds of mistakes in the chip and to ensure that the chip was compatible with those in other PCs. Compaq was also able to issue a version of OS/2 for its own machines almost immediately after IBM, because Microsoft had originally developed the program on a Compaq machine.[52]

Similar relationships pervade even traditional industries. Proximity helps automakers direct challenges to steelmakers, and the latter to offer their new solutions back. The geography of these linkages is influenced by the higher likelihood that such relationships can be developed with local industries. Propinquity can lead to faster turnaround times, a greater eagerness to concentrate on nearby problems, or less leakage of solutions to competitors. Kawasaki Steel sought to buy 40 percent of Armco in order to serve Japanese carmakers in America, who demand the same high quality of steel they find back home.[53] Why would a supplier of auto parts spend time and money developing, for instance, an electronic door-lock if there were nowhere to fit it on its biggest customer's new (and usually secret) line of cars?[54]

The developmental content of a linkage can be measured by the difference that its problems make. Large farm sectors spawned large local tractor industries to serve them. But, with innovation now the prerequisite for growth, the real question is whether America's farm sectors are better customers; are their demands more likely to spur technological development among their suppliers than the demands of other farmers? How do developments on the farm correlate to developments in farm machinery production? Do improvements in the production of food lead to problems that the domestic industry is best placed to work on and capable of answering? Can the answers be applied to problems in other sectors (e.g., construction)? Can other users gain an edge in international competition by enjoying preferential access to such equipment? Do advances in aluminum rolling promote advances in aluminum canmaking technology?[55] Does knowledge about advances in metal casting (near-net shapes) matter to aerospace design?

By such criteria, cobalt mining has minimal strategic content. Because cobalt is critical to defense and found in nonsecure locations, it may be worth stockpiling it. But mining it domestically confers no information and hence no developmental benefits to its users, and little to equipment suppliers.

It is hard to overstate the impact of linkages from buyer to seller on technological development.[56] Eric von Hippel of the Massachusetts Institute of Technology (MIT) found that a high share of new ideas comes from users; they account for over 60 percent of the innovations in semiconductors and over

70 percent in instrumentation.[57] A brief survey of the top eight corporate innovators established that at least four of them got that way by institutionalizing linkages with their customers.[58] For chipmakers, having potential customers (computer manufacturers) at home with their specialized needs, holds the key to retaining a position in specialized memories.[59] Akron's ability to pick up 3,500 new jobs in plastics machinery production is due to its plastic products industry; machine producers found that they had to be near their customers' engineering departments.[60]

Many large American companies that had earlier ignored the developmental potentials of their suppliers have changed their minds. Automakers, as well as General Electric, Motorola, and Xerox, have sharply cut the number of their suppliers, but they are bringing survivors more closely into their own development processes, ensuring that they build linkages through learning new technologies together.[61, 62]

The relationship between a factory and its suppliers often has large and immediate geographical impacts. Japanese automakers initially came here to assemble cars from overseas parts. Many partsmakers followed and, in so doing, helped to build a deeper automaking infrastructure.[63] The growth of the Japanese semiconductor industry was similarly supported by its dominance in the consumer electronics sector. The latter not only provided a virtually guaranteed market but also allowed the chip industry to test technologies early. Development expenditures could yield returns and, more important, market feedback earlier in the cycle. When the devices were perfected, they could be incorporated into more demanding uses in computers and industrial equipment. Recent trends toward shorter product cycles have reinforced the value to large electronics makers of controlling their own parts manufacturing. Matsushita, the world's biggest consumer electronics company, like Philips and Thomson, is putting more effort into making and designing chips.[64]

Having local buyers, while important, does not itself suffice to develop supplier industries. New England's defense contractors (Raytheon, Sikorsky, Pratt & Whitney, Electric Boat) fueled the growth of local subcontractors, as did those from greater Los Angeles and, to a lesser extent, Minneapolis, Long

Island, and Texas. But few subcontractors emerged in St. Louis (McDonnell-Douglas), Atlanta (Rockwell), or Orlando (Martin-Marietta). New defense plants (General Dynamics, Vought, Tracor) lured to the site of an old Army arsenal in Arkansas created few spinoffs.

Linkages to the business service sector have increased in importance as more firms have chosen to contract out what they used to do in-house. Business services range from high-skill professions (accounting, architecture and engineering, consulting, data processing, office automation, repair, software writing, and training) to low-skill professions (cleaning, protection, and temporaries). The more efficient and innovative a regional service sector is, the more it will affect business location decisions and the more the service sector itself will develop.[65] Again, it is the flow of challenges, not just business, that determines what linkages work. Do local clients generate problems requiring development? Are solutions applicable elsewhere? Are learning-curve and search efforts rewarded?

Linkages to workers come from incentives and opportunities to increase their education and experience. On-the-job production and management skills are one route. Employee involvement in management decisionmaking at the shop-floor level is another.[66] Others include making education a prerequisite for employment or offering in-house training and education, as well as subsidies or salary incentives for outside education. As one automobile executive noted, "High technology is not the only answer. You've got to develop a more skilled work force that keeps improving itself."[67]

Regional effects of education linkages can be considerable. Educated parents produce educated children; they create demands for quality in the schools and support infrastructures of libraries, bookstores, and computer services. Firms that support human capital investment seed the local economy with a work force that can attract sectors that need their talents, thus creating more education incentives in the general populace.

Horizontal linkages may be found in large corporations where problems from one division are presented to another; keeping the benefits of both problems and solutions in the same corporation captures the spillovers from such problem solving and can make it more likely to take place. Other such linkages are deliberately created from partnership.[68] Paul Lawrence, of Harvard, coined the term "value-added partnership (VAP)" to describe McKesson, a West Coast drug distributor whose theme was that each "player in the value-added chain has a stake in the others' success, [seeing the] entire VAP—not just one part of it—as a competitive unit."[69] But as Kennichi Ohmae points out, the linkage fails if it is not explicitly developmental, if "you're not trying to learn from it—or through it—[or if] you're not trying to grow to get better as a partner."[70]

The MIT Commission on Industrial Productivity found that two of the six fundamental weaknesses of American manufacturing stemmed from poor linkage formation.[71] One was the neglect of human resources by American companies competing against those overseas, who tended to regard themselves as

> learning institutions, where—through education and training—employees can develop breadth and flexibility in their skills and also acquire a willingness to learn new skills over the long term.

Another was a widespread failure of cooperation within and among companies.

> Suppliers and even customers have also been kept at arm's length by the management of many U.S. companies in spite of the fact that such vertical linkages can be conduits not only for raw materials and finished products but also for technological innovations and other developments that enhance productivity.

As such, industries suffered because they had yet to view themselves in a strategic context.

Corporate and Local Networks. When first analyzed in the late 1960's, the growing role of the multinational corporation implied a shift from nations to the multinationals as the building blocks of the world economy. Economic competition between America and Germany, for instance, was mediated by that between Ford and Volkswagen.

Corporations were where decisions were made, resources allocated, and information exchanged. Countries were simply venues for operations.

Over the last 20 years, the degree of corporate multinationalization has grown, but the locus of composition has shifted from corporations to communities of information. Such communities are likely to share a common language and government, and often a common location, such as a metroplex.

The impetus for this swing back has been a shift in the network for exchange of information and opportunities. Big firms were once characterized by strong vertical integration. Orders, information, and opportunity resided within the corporations. Interactions with outsiders were limited to labor and commodity markets. Multinationalization, in this context, extended corporate unity across national borders, canceling or transforming intranational hierarchies.

Corporations are now more likely to be organized as profit centers, even to the extent of turning divisions into virtual companies paying dividends (as Matsushita has done).[72] Why this change? Many management theories now favor decentralization and leaner corporate structures, whose divisions can be managed by the numbers (thanks to more sophisticated financial analysis tools). Many profit centers are facilities given birth by strategic intercorporate alliances. The migration of computer power from the corporate to the departmental and desktop level has also supported this change. So has the increased sophistication of overseas governments and America's regions in inducing multinationals to create independent linkages.

A profit center orientation forces each center to justify its own existence. Independence follows. Centers cannot so easily be constrained to use the products, services, and workers of sister divisions if they have to live or die solely on their own performance. Headquarters are not immune; if their services cannot be justified, Wall Street will, as it did with Beatrice, find ways to eliminate them as well.

Once profit centers are free to create or exploit information networks to their own advantage, they do so. The primary result has been an increased level of outsourcing for parts and services, creating entrepreneurial opportunities for new providers.[73] Networks of opportunities are themselves developmental links. With this scenario comes a change in emphasis from the corporation to the information network as the locus of development. Thus, regions become central, with corporations then becoming their participants.

The importance of such networks may also shape the debate over the importance of basing development on large corporations rather than small ones. Is development more soundly based on large corporations (as Charles Ferguson argued for large corporations in scoring "excessive entrepreneurialism")[74] or small ones (as George Gilder argued for entrepreneurs, preaching the "law of the microcosm")?[75]

IBM clearly is not Silicon Valley. The former is a highly integrated organization and commands strong loyalties from its workers and suppliers. Information leaving IBM is tightly controlled, so it can develop new products and processes and capture their secondary benefits. Many of the challenges from one part of the firm are solved in another. IBM (and Japanese electronics firms) can afford to invest in their workers and suppliers because they can confidently expect to capture the results. Both can afford to support advanced if not always profitable semiconductor operations because they can make exclusive use of the information so generated. But the degree to which IBM's networks are self-contained keeps it from being a better engine of growth. IBM's presence in upstate New York or Vermont has not sparked much regional activity there, compared with, for instance, Kodak's in Rochester. Its ratio of exports to sales is the lowest among America's 20 largest exporters,[76] while it is the fifth largest exporter in Britain and the third largest in France.[77] There is also the risk that many developmental paths may lie fallow in large organizations because they threaten a firm's capital base.

The alternative—Silicon Valley—model allows development to hopscotch from one industry to another, creating outside linkages that let technological developments transform entire economies. Some companies, such as Hewlett-Packard and Fairchild, have involuntarily spun off employees who sought to explore such opportunities at the company's cost but the region's gain. Kodak, Tektronix, and

Control Data favor a more deliberate approach but seek to keep equity interests in such spinoffs.[78] Yet this model, despite its dynamism, suffers because many of the benefits of long-term investments cannot be captured for the investor. Worker mobility is high, and information flows widely. What one company gains by linkage, another loses by leakage, so that the lack of a stable institutional production structure inhibits long-term investment.

Paradoxically, the distinctions may cease to matter at precisely the point where they have reached public debate. As noted, large corporations are giving way, in Tom Peters' words, to cooperative networks, in which small corporations are capable of doing big things via networks of partners. [79] Kennichi Ohmae argues for the inevitable "global logic of strategic alliances."[80] Apple's John Sculley foresees a model built on interdependencies with other companies, suppliers, and spinoffs to gain greater flexibility.[81] As large corporations decentralize and small corporations build alliances, they start to work in the same way.

Gateway Nodes in the Linkage Structure. To account for differences in growth rates by differences in access to information may appear strange when, as the *Economist* observed, the raw material of today's growth industries is a weightless "information" transported instantaneously through the ether.[82] But it is precisely because explicit information is so footloose that implicit information is so valuable.

An activity that needs only commodity information will migrate to low-wage countries with a sufficient supply of technical manpower. If America's advantage over these countries were only its educational system and its natural resources, how well could it keep its place in the world? Rather, it is precisely because America has built hard-won communities of information that it can hope to continue to exercise economic leadership. These communities of information extend in many directions, down to workers and suppliers, across into services and universities, and up to industrial buyers.

An economy whose competitive edge is its network of information activities, however, is vulnerable to the strategies of companies or countries that target the critical nodes in the network. Those who control such nodes control the gateway to a collection of other technologies. If the latter are growth engines the success of one nation can confine another to sectors with poorer growth prospects. In one sense, international competition in technology is like a game of Chinese checkers, whose point is to capture enough links and nodes to clear a path to the goal while denying opponents access. Success in this leaves few obvious entry points for overseas entrants to gain new access, even in a long technology chain.

Do gateway nodes exist? Some see the semiconductor industry as one; others see the semiconductor machinery industry as a prior gateway.[83] The Real-Time Operating Nucleus (TRON) project reflects a Japanese belief that control over microprocessor technology is the gateway for microcomputer and workstation access.[84] Operating systems appear to be the gateway technology for mainframe computers. The hot sections of a jet engine contain the gateway technology for the engine as a whole. Project management for systems integration appears to be the gateway node for aerospace, something that Boeing rediscovered when it noticed its Japanese partner on the 767, MHI, asking a disproportionate number of questions on that topic.[85] American Airlines found that its Sabre airline reservation system can be used as a gateway technology, generating up-to-the-minute information used in shuffling fares quickly.[86]

Gateway nodes keep better when industrial leadership can be expected to persist from year to year. Patents confer some persistence, depending on how difficult it is to innovate around them. So does localization of the technology in a tight community enclosed by a company or country. Tacit information keeps better than information that can be written. Process information generally keeps better than product information, because the latter is easier to reverse-engineer on inspection.

The best route to preserving a gateway technology is to continue to improve it. One path is to build virtuous circles—those that ensure that one generation's volume producer will also have the lowest prices and the most applications and, in turn, the largest market share. Such firms can force their competitors to give up or accept a low-volume niche that does not teach the skills necessary to compete in high-volume applications. A firm may also develop technology in such ways that experience leads to systematic improvement. Temporary superiority in a technology can also be used to pose developmental problems that encourage the market to remain committed to the technology.

The existence of gateway nodes and their recognition as such by others suggest that if America falls behind Japan or other competitors, the trek back will be difficult or impossible. The transitory setbacks in market position will be reinforced by learning-curve economies and ever tighter product-development cycles. Loss of gateway technologies gives others the high ground in threatening associated industries that could otherwise provide a platform for a comeback.

Leading-Edge Sectors as Engines of Growth. So, what makes industries strategic? In order for a nation to maintain an edge over newly industrialized countries, it needs to find activities that allow it to increase mastery continuously. Such activities must reward the investment of capital, not just financial and human capital (although they are important) but network capital. In the last century, railroads were one such leading-edge sector. The problems of spanning the country spawned markets for steel and engineering and created opportunities for manufacturing by reducing transportation costs.

Today, creating a strong local information network, built through the continual exchange of interesting problems, can place areas in enduring competitive positions in the world economy. Economies whose networks are concentrated in growing markets can more easily look forward to improving terms of trade with the rest of the world. Staying in such markets, however, requires that an economy's network learn faster than that of the competition. Developmental linkage is what keeps everyone moving ahead together.

IV. THE STRATEGIC CONTENT OF KEY INDUSTRIES

> The multiplication of manufactories not only furnishes a market for those [agricultural] articles.... but it creates a demand for such as were either unknown or produced in inconsiderable quantities. The bowels as well as the surface of the earth are ransacked for articles which were before neglected. Animals, plants, and minerals acquire a utility and value which were before unexplored.
>
> *Report on Manufactures*
> Alexander Hamilton
> December 5, 1791

THE CONCEPT OF A STRATEGIC SECTOR may be operationalized in two ways. To what extent do an industry's markets and technologies predispose it to be strategic? To what extent do its actions live up to its potential?

We will examine sectors that have been described as the past and present cornerstones of some major economies: agriculture (United States), fashion (France), chemicals (Germany), motor vehicles (United States and Japan), semiconductors (Japan), and military aerospace (United States).

Agriculture. Although America is normally a net food exporter and can expect to keep its overseas grain markets, growth prospects are not promising. Food is a commodity subject to inordinate levels of protection in both rich and poor countries. Long-term declines in commodity prices tend to cancel vigorous gains in output per farmer.

Agriculture's linkages support a large penumbra of supplier industries and a large work force, but both are too agriculture-specific to help the rest of the economy. Neither farmers nor farm services are likely to help develop other sectors, even though agricultural research itself can generate useful spillovers. The industry's downstream linkages are important to the food industry but not developmental per se. Access to large, cheap supplies of food does not create interesting problems; variety and innovations in crops matter more. In that regard, American farmers may not have been as agile as others (Dutch or Chileans) in responding to shifting consumer demands for higher value produce.[87]

The developmental value of agriculture's linkages to supplier firms is mixed. The farm machinery industry is mature and innovates at a modest pace, but only 10 percent of its innovations come from users.[88] Its world leadership position, built from leading-edge demand for farm equipment and economies of scale, is being challenged by makers of smaller implements—which American firms have only started making—who honed their products on third-world markets.[89] A case can be made that the farm machinery industry has opted out of foreign markets by concentrating on the huge and expensive machines that are appropriate only for American-style farming.[90] By contrast, agriculture's linkage to biotechnology (e.g., new seeds and growth hormones) may spawn a leading-edge domestic industry by supporting process technologies that can also be used in health sectors.[91]

Fashion. The fashion industry takes in those parts of the clothing, cosmetics, consumer wares, and jewelry industries, among others, whose primary selling feature is a prèmium brand name.

The industry generally has good growth prospects even though it generates few technologically demanding questions. It also makes a good export sector. Most of the value added stays at home, even if production facilities are displaced to low-wage locations. Income elasticity, and hence growth, is high. Up to a point, good trademarks can impart glamour to otherwise unrelated products. Since success in the fashion industry requires access to affluent consumers, the design end is unlikely to drift to third-world countries.

Linkages, however, are harder to assess. The industry rewards creativity (as basketball rewards height), but does it do so in such a way as to encourage its growth? Linkages to suppliers can be developmental if they require suppliers to develop quality control procedures, but are they necessarily more likely to arise from the fashion industry than from any other? Will solving the problems of fashion companies lead to systematic knowledge that keeps them competitive in the next round?

The fashion industry illustrates dangers in classifying a sector on the basis of expected growth rates. Although textiles are a classic declining industry, American manufacturers have, since 1986, tried to capture a larger part of the fashion end of the clothing industry (roughly 40 percent of the total). By accepting orders for shorter and more frequent production runs and reducing the time it takes to fill an order, they are working on problems in ways that suggest successful, not supposedly failing, industries; producers in other countries have done the same.[92] Finally, textiles themselves may be useful if they can provide a place where immigrants can learn an industry on their way to full absorption into the economy.

Chemicals. The chemical industry may be divided into specialty chemicals, commodity chemicals (mostly petrochemicals), and drugs.

Specialty chemicals have most of the attributes of a strategic sector. Growth rates are high. The industry supports and rewards education. There is continuing development and a high level of new-product introductions. Intelligent early users of chemicals have developmental advantages over latecomers. America is a net exporter of chemicals; the industry is one of the few in which America dominates the Japanese and in which they still license technology developed here. Kodak and 3M illustrate the leverage that working in chemicals can generate for entry into other lines of work.

By contrast, commodity chemicals (mostly petrochemicals) lack some of these attributes. Growth prospects are only fair, and while workers need strong skills those skills may be hard to transfer elsewhere. Petrochemical plants are strongly linked with each other through common requirements for services, construction crews, and, on the Gulf Coast of the United States, pipeline networks. The Persian Gulf, despite its oil, failed to break into markets in large part because it lacks such linkages. By 1990 it will only produce 3 percent of the world's ethylene, the primary petrochemical building block.[93] With the weak exception of natural gas output, petrochemical plants do little to spur the production of feedstock supplies. Many of the industry's other inputs, notably construction crews and machinery, have been effectively internationalized and do not create local or even national linkages. Systematic learning as a competitive factor is vitiated by the tendency of newer rather than more experienced plants to have the lowest costs.

Strategic content cannot be assessed in isolation. Does producing large supplies of petrochemicals spur research in uses that will turn more of them into end products? The Gulf Coast was able to leverage its refineries into a petrochemical industry but not into a specialty chemical base. The information generated by producing petrochemicals apparently did not yield much competitive edge downstream.

The pharmaceutical industry enjoys high growth rates because drugs solve an increasing number of problems efficiently. Educational levels, rewards to education and rewards to educational institutions are very high. Expertise in developing drugs in one year generates systematic advantages in solving drug-development problems in the next. The threat of competition from the third world is still minimal in development and modest in production. But linkages from the industry to other sectors are mediocre. Inputs to drug development are a small percentage of value added, can be sourced internationally, and present few interesting problems to solve. Research, a large share of the industry's costs, gives interesting problems to instrumentation companies, but the linkages so created are largely international. It is only a modest advantage for a drug-using sector (medicine) to be in the same region or even country where the drug is developed.

The use of chemicals as a strategic sector also depends on Government policies (e.g., Food and Drug Administration. Environmental Protection Agency, Occupational Safety and Health Administration, product liability laws) to screen chemicals.[94] There are strategic implications for methods that can prescreen them without inhibiting incentives for innovation.

Motor Vehicles. Despite limited growth prospects, automaking, by posing interesting technological problems, could, in fact, be strategic if it behaved appropriately. Otherwise, the industry is no more valuable than its growth rates suggest; with vehicle registration in the United States at a plateau, remaining growth markets are in the third world (which the Japanese exploit better than American companies do) and upscale markets (which Europeans exploit better).

Some of the industry's linkages have modest, if even positive, value. That the American car buyer gets the world's largest selection is due to Detroit's weaknesses rather than its strengths. High wages for semiskilled work may have increased the money to support college education, but they lower the incentives to attend.[95] Wage and salary levels in greater Detroit have inhibited companies from locating there unless they make cars or sell to those who do.

Linkages to suppliers could be very positive. First, the industry is huge; the domestic industry accounts for a third of the machine tools and almost half of the robots sold.[96] Second, the industry has spawned many interesting problems: weight reduction, power enhancement, new materials, electronic controls, etc. But Japanese and European producers have probably generated better linkages than American ones by taking up advanced parts and subsystems in their vehicles more rapidly. Among these are four-wheel steering, map displays, anti-lock brakes, ceramic engine parts, active suspension, and multivalve engines.[97] In America, because subcontractors account for only 40 percent of the value added to a car (versus 55 percent in Europe and 70 percent in Japan), solutions developed here proliferate more slowly than they do overseas.[98]

Semiconductors. This industry has a high strategic content by almost all measures. Growth rates are high (if erratic); development is rapid, and productivity increases sharply every year. The work force is well educated, and rewards to education are high. Its engineers can (and do) move easily to other sectors. Strong, two-way linkages exist to universities and to venture-capital services; both also support the growth of related sectors.

Specialists in particular semiconductors (e.g., 64K DRAMs) have an advantage in preparing the next generation of chips (256K DRAMs). However, the leaders producing radically different next-generation chips are often far different from those in general-purpose silicon chips even if, as often happens, they are from the same area.

Linkages downward to suppliers of production equipment are strong. One of the prime purposes of Sematech, for instance, was to unite chipmakers and those who made their machinery in technology development. The singular demands of the industry for production equipment made the American equipment sector the world's largest, with roughly half of the world market.[99] The most important linkage, however, is to users. Although commodity chips flow internationally, U.S. users can count on a head start in getting and learning about chips developed here (as can Japanese users for chips developed there). Apple Computer developed in Silicon Valley in part because it was easy to buy chips off the shelf there. Moreover, the presence of a strong industry gives users a wide choice of people to work on their specific problems. Market opportunities also incline local semiconductor firms to work on problems that local customers expect to encounter.

Military Aerospace. Were DOD the American MITI, military aerospace would be the leading-edge driver for the economy. Assessing its real contribution, though, requires looking hard at exports and developmental linkages. Neither is compelling despite the industry's heavy R&D inputs and its trail of eventual spillovers.

America still exports military aircraft and parts, but growth prospects are poor, and competition from other countries is getting stiffer. American hardware suffers from perceptions that it is too costly and complicated for other countries to use.[100] The industry's customers are other governments, who have one eye on their own potential producers. When forced to import, they often require sizable offsets to reduce their own trade deficit and learn the technology. Information flow and associated linkages are forced offshore as part of the bargain.

The industry's linkages are not as developmental as claimed. Employees are well educated, but, as the 1970 recession showed, they are highly specialized and difficult to redeploy outside the industry. Expertise in product and process development, however, endures and even widens from year to year.

Military work generates problems that are technologically interesting but do not necessarily create linkages in ways that influence international trade very much. The bifurcation of military and commercial production inhibits the transfer of technology between producers working on similar problems. Of the two exceptions, computer services is a declining market, but commercial aerospace, where the linkages are strong, has strong growth prospects. Otherwise, though many commercial products can be traced to military research, the time lags are getting longer, commercial product cycles are getting shorter, and international diffusion is getting faster.

Implications of Strategic Content. If one likens the world economy to a gigantic game of gin rummy, then the ability to rate the strategic content of industry is of some importance in building a winning hand for a nation or a metroplex.

Strategic content is more than just counting externalities: true economic theory can be used to favor activities that generate positive externalities, but they are hard to measure. More to the point, the process of assuring dynamic competitive advantage involves conscious decisions to coordinate factors—education, research and development, public infrastructure, capital flows—that work either with or against each other. Favoring agriculture forces certain decisions on trade negotiations, immigration policy, land use, nonpoint environmental controls, and transportation investments (to name a few) in one systematic manner. Favoring software development forces parallel decisions on trade negotiations, immigration policy, intellectual property, university education, and telecommunications investments in another systematic manner.

Still, is the point to pick winners? On one hand, doing the job as well as the next guy (read Japanese) is a simple process.[101] Several years ago, a delegation from DARPA to be sent to Japan amassed what it thought were the critical winner technologies and discovered that the list was identical to Japan's. On the other hand, we tend to forget the winners who lost (table 2).

Table 2. High-growth industries for the 1980s from Japan

Energy	Systems	Materials
Coal liquefaction	Supercomputers	Optical fibers
Coal gasification	Space development	Ceramics
Nuclear power	Ocean development	Amorphous materials
Solar energy	Aircraft	Efficient resins
Deep geothermal energy		

Source: MITI as quoted in *Business Week*, 30 June 1980.

Ten years later, this list is a poor representation of Japan's achievement in this decade. None of the energy industries, with the possible exception of nuclear power, have done much. In systems, despite multiple Japanese efforts, America still has the undisputed lead in all four listed. Japan has achieved success only in the materials listed, and real success only in the first two.

The significance of a strategic perspective does not lie in its lists but in insights. There are richer avenues for industrial strategy, as the next chapter demonstrates.

V. PERSPECTIVES ON DEFENSE POLICY

> The extreme embarrassments of the United States during the late War, from an incapacity to supply themselves, are still a matter of keen recollection.
>
> *Report on Manufactures*
> Alexander Hamilton
> December 5, 1791

DEFENSE TECHNOLOGY POLICY MAY seek two goals. The obvious one is to maximize the rate at which technology is developed and inserted into military systems. The less obvious one is to take advantage of the enormous sums available for technology development in defense in the hopes of enhancing technology development in nondefense areas as well.

The Costs of Dichotomy. At one time, the second goal was thought to be a subset of the first; DOD's search for technology automatically created spillovers that promoted our international trade position. Typically, DOD, in seeking new technology, would fund American companies to do R&D and then would buy the first production units. Learning-curve effects would reduce production costs. With more users would come new applications and software. As users familiarized themselves with the technology, demand rose. More DOD systems took up the innovation; so did selected commercial applications here. The interplay between increasing production and decreasing cost created a virtuous circle. Markets for the innovation widened, and at some point American firms exported. By so doing they laid first claim to the world market. Overseas manufacturers struggled to catch up, but this took years; by then, American producers had gone on to yet another innovation.

The development of the computer, semiconductor, and jet engine industries echoed this model, but today it scarcely applies.[102] Most of the reasons for the cycle's breakdown can be ascribed to the wide breach between the worlds of commercial and defense technology development.[103] Intelligent promotion of technologies by DOD may lead to their development and even use. But the companies that DOD made smart are rarely capable of leaping between military and commercial technology.[104] Some would argue that low-volume, high-reliability defense work does not prepare a firm for high-volume commercial work. A larger obstacle may be the difficulty of bridging utterly different management, sales, and service requirements.[105] Commercial producers, in turn, must hurdle Government regulations, differences in culture between the two sectors, and the esoteric technological specifications imposed on military hardware. Technical computers have made the leap precisely because they never had to be built to MILSPECs (military specifications) to begin with. Although DOD policies can control such problems, trends favor more bifurcation. Sunstrand, for instance, which had been docked for major contracting irregularities, spent millions to separate government and commercial production in its facilities.[106]

The breach is pervasive and deep. Many prime contractors, such as General Dynamics, Lockheed, Northrop, and Martin-Marietta, have few clients outside the Federal Government (and foreign military sales), and little business other than aerospace and computer services. At the first-tier subcontractor level, 80 percent of those who make tactical missile parts do half of their business with the Government; half do at least 80 percent.[107] Since primes and first-tier subcontractors together provide over 80 percent of a missile's value, very little of what goes into a missile benefits directly by association with commercial business. At the vendor level, facilities that produce military/aerospace electrical connectors are different from those that produce commercial connectors; the same is true for precision castings. Forty percent of all military chips comes from firms that depend on defense for at least 30 percent of their market, even though DOD accounts for under 9 percent of total sales.[108] Even dual-market chip companies—IBM, Texas Instruments, Intel, National, or Signetics—separate their military shops from their commercial shops by hundreds of miles.

Little elaboration is needed to argue that DOD patronage of dual-use sectors can provide additional seed money and early intelligent customers to accelerate the development of commercial technology.[109] Of more relevance to defense is the way in which a dichotomized industrial base hurts DOD itself.

Foreign dependence and defense dependence can both lead to less access, as figure 2 illustrates. The former may inhibit DOD's access to overseas technology; but the latter inhibits the defense industrial base's access to the commercial world, which hurts even more.

A Defense Science Board study of software found serious shortfalls in defense buying practices, stemming from—

> insufficient procurement of non-developmental item software, weak productivity incentives, heavy regulation that inhibits software firms from using familiar commercial practices, unreasonable data rights requirements, and a bureaucracy that forces too many layers of request-for-proposal writers between the software types and users.[110]

Another such study generalized this to—

> increasing risks that the United States is losing the technological advantage [because] DOD is getting progressively less for its R&D dollar. [With the] growing overlap between technology advances in the commercial and defense sectors . . . improved performance of the DOD technology base can contribute to the ability of the United States to compete in the international marketplace.[111]

There are many reasons why military spending alone, despite its large R&D component, would have difficulty supporting a leading-edge industrial sector. Small production runs deprive producers of both revenues and manufacturing practice. The lack of a wide customer base means that only one or, at best, a few solutions to problems are ever used. The commercial world, at least when technologies are born, supports more alternatives before winnowing starts.

Large, wide markets also spare buyers from having to test products themselves. When DOD buys a unique

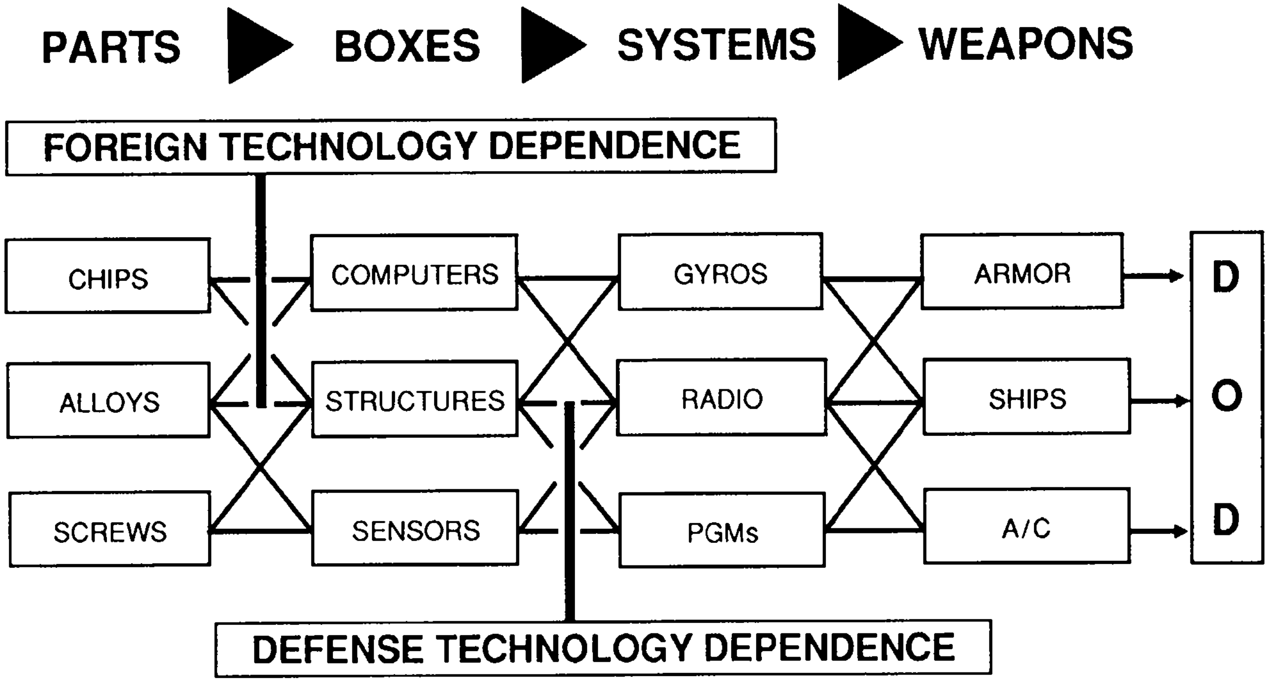


Figure 2. Defense dependence resembles foreign dependence — both of them weaken and narrow linkages among what should be closely related manufacturing/technological activities.

product, it can tap no such information base. Instead, it creates a set of intervening specifications. One set of specifications qualifies particular producers to make particular products. Another set stimulates quality and reliability by reference to intermediate tests of historically correlated factors. Such specifications drive up the cost of production, thereby cutting quantities, fueling the drive for documented performance for those remaining, and thus adding more tests. Many tests, based as they are on lessons learned from old technologies (especially electronics), are obsolete.

Electronics is where the split hurts DOD worst. The long process of qualifying a commercial chip to DOD specifications means that defense houses get chips 3 to 5 years later than commercial firms do.[112] In 1978, DOD responded by starting its own advanced chip program, VHSIC (very high-speed integrated circuit). Although VHSIC met its technical goals, chips from the program are unlikely to be used in volume during this century. DOD's standard avionics processor, the 1750A, is still a 16-bit chip, and its successor, the 1750B, keeps the same architecture and only adds optional enhancements.[113] The French military, by contrast, has adopted a militarized version of Motorola's 32-bit microprocessor, the 68020, as its standard.[114] Meanwhile, computer-driven avionics gear in military aircraft still depends on electromechanical power management.[115] A recent Navy study concluded that it could improve its computers and save millions by abandoning its requirements for specially developed computers and dropping its shock and vibration requirements.[116]

Without a commercial base, technologies such as VHSIC risk a vicious circle of low production and low demand. Program managers have been slow to use VHSIC chips because they are new and their price is high. As a result, producers are behind on their learning curves, applications are few, and software is far between. This, in turn, retards VHSIC's uptake, and so on. Had VHSIC technology been developed for commercial markets and taken up by DOD, a larger base would have supported the volume (and revenues) necessary to improve price, performance, applications, and software faster and thus interest project managers sooner. Instead, purveyors of VHSIC complain that demand has not been anywhere near levels that they and DOD had foreseen and that the Motorola 68020 is winning design-ins everywhere.[117]

The Challenge of Industrial Integration. DOD's challenge is to break the association between defense contracting and the inability to compete in commercial markets. An industry-strategic perspective would first ask how R&D can be used to foster not only technology but also the industry that could sustain the technology. The two are not the same; the latter question must entail market structures and inclinations.

All too often, a pattern develops of American companies developing products for military uses and foreign companies doing the same for commercial uses. An American corporation, Raychem, leads in the technology of shape-memory metals, for instance, selling about $30 million worth of couplings and fittings to military users. Japan's leader, Furukawa Electric, is looking for applications in louvers, rice steamers, fishing lines, and dentistry.[118] Japan's market may be smaller now, but whose path offers the more certain route to long-run technological superiority? The same may be observed for charge-coupled devices, electronic arrays for real-time image digitization. Kodak, having been among their inventors, ceded the consumer markets for such devices to the Japanese.[119] Now it has a very large, picture-quality grid (2,000 by 2,000 pixels) that offers 10 times the resolution that Japanese firms offer.[120] At roughly $25,000 a copy, Kodak's markets are confined to defense systems. Practice and user feedback may help Kodak vie for larger markets, but how DOD officials deal with this technology will influence the directions in which it is developed.

To promote the development of GaAs digital chips, for instance, DARPA funded production lines. The companies that won contracts were AT&T, Rockwell, and McDonnell-Douglas, not the small companies such as Triquint, Vitesse, Gazelle, and Gigabit (albeit founded by refugees from the Rockwell line) for which "it is a case of GaAs or nothing."[121] No one disputes the importance of designing, demonstrating, and testing GaAs circuits in the military systems as a prerequisite to building the technology.[122] But in the process of developing technology, DARPA should also be interested in whether its clients are best situated to develop both commercial and military applications so as to move down the learning curve as rapidly as possible.

There should be ways to support industry-building without harming technology-building. Inducing start-up companies to play may require placing less emphasis on a company's ability to respond formally to proposals and more on its intrinsic capabilities and motivations. Holding back on developing specifically military features—radiation-hardness and temperature-insensitivity—and concentrating on generic improvements in GaAs technology might have interested the commercially oriented producers more. In another technology, DARPA's boast that 40 percent of its superconductivity budget goes to firms outside the defense industry shows how far it has yet to go.[123]

Without an explicit strategy, DOD's policy of pushing technology in weapons procurement would still create some spillovers. But the interval required for technology to migrate from military systems to commercial ones is sufficiently long to give overseas competitors time to get in on the technology first. Channeling these spillovers to national competitive advantage may require policies that would encourage those who do R&D to get to market early (or would fund R&D for those so inclined to begin with).

Acquisition: Systems, Scale, and Factories. The next step in building an industry is sustaining the technology from development to the learning-curve stage.

DOD's ability to grow technologies is not helped by long systems-development times. Weapons systems typically have their specifications written 10 years earlier.[124] Even if they were written based on the current state of the art, they are 10 years old when first fielded (if not older, given all-too-frequent years of delay). Not all technology specified is so seriously dated; some is based on a guess of what will be available or can be developed by 1990 for incorporation. But such guesses are subject to errors of pessimism and optimism. The optimistic guesses take the form of requirements that the technology is not ready for; getting it to work delays the entire system and makes all the other technologies in it that much more out of date. In the meantime, long valleys between design and production make it hard to retain producers of technologies developed for DOD, such as VHSIC and microwave-millimeter integrated circuit (IC) substrates.[125]

Rigid design specifications can also inhibit innovations by blocking their most common paths. Why? Changes in technology mean changes in many different attributes. New technologies are likely to make at least one attribute worse. The jet engine improved speed at the expense of fuel mileage. Computers made big calculations possible but broke down more often than manual calculators. The incorporation of virtually any new technology creates at least schedule risk. If the existing technology meets all the minimal requirements and the new technology improves on most but not all minimums, the old technology is within specification and is retained.

Finding ways of backfitting technologies into weapons systems at a later stage in their acquisition cycle would support them better and enhance the defense systems which use them. The trick is to do so without resurrecting problems of systems integration that took a long time to solve in the first place.

The commercial software industry has long wrestled with this problem. Because computer programs contain thousands of parts, each of which can theoretically affect all others, requirements for systems integration grow faster than program size. The more modern computer languages (e.g., Ada, Smalltalk) have thus been designed to minimize the problem of controlling the effects of certain processes on others.

Similar modularization technologies may prove equally useful in military systems. Intelligent interface design can limit the deleterious impact of systems integration on subsystem innovation. Permitting reconfiguration without affecting interprocess communication would allow innovation in module design without the painstaking retesting of the whole system. The Japanese, for instance, are developing a form of catalog engineering in which new systems are cobbled together from mostly standardized parts, threatening the dominance of other suppliers in building expensive custom-made items (such as German machine tools).[126] Getting interface design correct is central to the development of many technologies, such as chips, graphics computation, electrical connectors, and flexible machining systems.

The creation of learning-curve economies is equally important even if it involves recognition that only a small share of the technologies that emerge from the labs can be funded on the scale that proponents believe they merit.

There are many ways of building scale. One may push technology out the door early in the form of spare parts, system upgrades, or small, stand-alone systems. Japan's technology corporations, for instance, generally emphasize getting a product out the door over assuring a perfect fit to market requirements.[127] Production bugs are worked out well in advance. Fine tuning awaits user feedback. By contrast, the defense resources spent on fine tuning requirements greatly exceed those spent on fine tuning production lines.

Purchases of end items can build scale in component production. Military requirements for supercomputers could justify massively parallel computers using GaAs Reduced Instruction Set Chips of the sort DARPA funded Texas Instruments and Control Data to develop.[128] DOD could also create an entire market to fill an old need in a new way. Putting personnel records on smart cards (credit-card sized computers, in effect) could greatly simplify keeping and accessing such records. It would also create a huge market for several key technologies: chip packaging, static computer memories, and media-based software. Scale can also be built through the wholesale substitution of one technology (ASICs, or application-specific integrated circuits) for another (hybrid integrated circuits) across a wide range of weapon systems.

Another path for technology development is to favor technologies known to have dual-use potential. A SQUID (special quantum interference device) can be used in inhibiting corrosion and in detecting submarines, as well as in hospitals; and the product also provides a good platform for developing high-temperature superconductivity.[129] Other technologies might include flat-panel displays (see below), shape-memory metals, ceramic engine parts, or robotics-grade sensors.

The promotion of factory automation is another area where DOD patronage and support could help to catalyze America's industrial revitalization. Currently, aerospace producers are leading the way in manufacturing AI (artificial intelligence), whose goal is "computer-integrated enterprise."[130] Again, the challenge is to enhance the development of such technologies (manufacturing technology accounts for less than 1 percent of DOD's total R&D budget), and also to diffuse such enhancement throughout the rest of American manufacturing.

Taking such changes together, figure 3 shows what a reoriented defense acquisition process might look like.

Defense Trade Relations. Once an industry is developed and built to scale, questions arise over the choices DOD faces between maintaining the industrial base and taking advantage of technical abilities available overseas. The question comes up frequently. Direct imports (Durandel), binational contractor consortia (Army field radios) and joint development programs (the RAM missile), licensing agreements (fighter-experimental, or FSX), subcomponent purchases (rocket motor casings), restricted procurement (optics), and offsets for weapons exports (Patriot missiles) all pose similar questions.

The static issues are straightforward. Allowing imports gives DOD access to superior economics and technology, supports rationalization, standardization, and interoperability with allies, and makes it easier for them to buy from us. Domestic sourcing preserves jobs, mobilization capacity, and a potential technology base.

The dynamic, and hence strategic, issues address the relationship between DOD's sourcing policies and the relative distribution of technological development. To source is to ask questions; it would be ideal to keep the developmental problems at home and let the less interesting ones leave. General

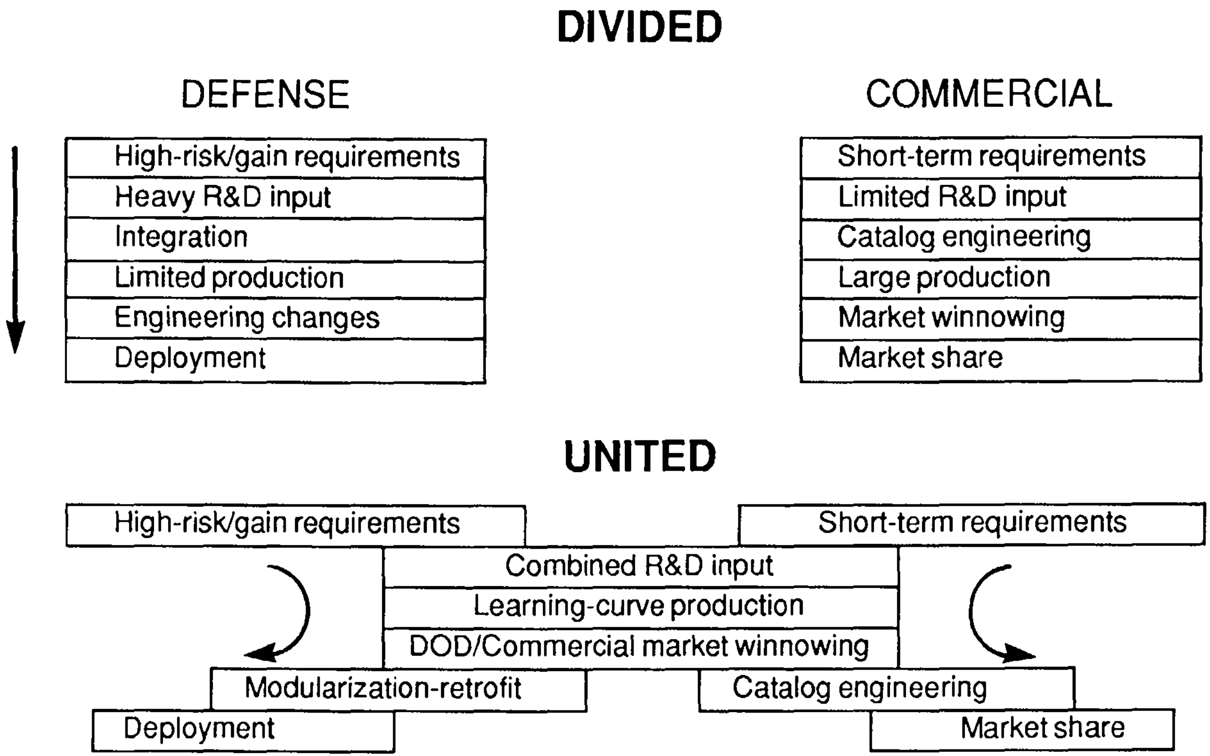


Figure 3. Divided versus united development paths

Dynamics' insistence on getting wing work on the FSX illustrates its understanding that the mere transfer of composites manufacturing technology (from the Japanese) without the opportunity to practice it is not developmental.

In bilateral negotiations, two countries would both like developmental questions. Since what is developmental for one may not be for the other, a deal can benefit both. But will such a deal build another country, such as a Japan, into a potential competitor in aerospace? As the *Economist* argues, "To judge by the straws of the SDI bids, Japan will sooner or later blow a howling gale through the world of defense contracting . . . ."[131] At present, the *Economist* notes, Japan is somewhat hindered: "[Because] exporting weapons [from Japan] is forbidden, companies have not been able to gear up to produce large quantities of guns, tanks and defence electronics, but [such] constraints are starting to ease. Japan's arms industry is poised to take off . . . ."[132] The same publication foresees that the Japanese "will have an increasing role to play in providing some of the advanced technology for most modern weapons."[133]

Licensing as a form of control is not ironclad, especially if practice at solving problems allows industries to innovate around the licenses. The gateway technologies may have to be identified to ensure that they do not leave except in trade for counterpart technologies. In the case of Japan, Ryozo Tsutsui, Japan's head of military R&D, observed that the country was competitive in two of the three basic technologies for making weapons—electronics and fine mechanics—but that it lagged behind in the third—large systems.[134]

Similar questions arise in controlling exports to friendly countries as a way of preserving America's superiority in key technologies. From a developmental viewpoint, the decision not to export a product, which is to say an answer, may create unusually high incentives for another country to pose the interesting problems. The French accelerated their development of computers in the 1960's when they feared being prevented from buying ours. They are considering the same in high-speed chips, due to DOD's restrictions on VHSIC exports.[135] As Japan's equivalent of DOD's acquisition chief remarked, "We are not worried about a cut-off from the U.S. [because] it would give us a great reason to embark on more of our own development programs.''[136]

Conclusion. The contrast between economic competition with allies and military competition with adversaries has been used to suggest that concentration on one invariably results in falling behind on the other. Those who would concentrate on military competition regard it as paramount because failures there are fatal. They further note that economic competition takes place among allies with similar social and political mores. Those who would concentrate on economic competition point to an inevitable correlation between economic and military power. They note the transitory nature of alliances compared with the permanent nature of interests.

Yet, only at the most superficial level must choices be made between competing in one or another sphere. There is no guarantee that reductions in military spending would be automatically redirected into investment or R&D. Although both military and commercial sectors draw on existing pools of technical personnel, the size of the pool is in no way fixed. One might as well blame soaring health care costs for draining resources from investment.[137]

The notion that more plowshares can be gotten only by beating swords overlooks how advances in sword technology may enhance plowshare technology. The same technologies are revolutionizing both civilian and military industry in the rest of the world: miniaturization, electronics, new materials.[138] There is much to be gained from breaking down the barriers between the two.

A Paradox. DOD may be better off putting resources into technologies in which foreigners are weak rather than strong. As a user of technology, DOD depends on the technology it can get, not necessarily the technology America can make. Even if America's industry improves from 5 years to 2 years behind its most advanced competitors, the best technology DOD can get is still overseas. DOD would be better off if America's industry improves from 2 years ahead to 5 years ahead, thus improving the best technology DOD can buy.

VI. PERSPECTIVES ON COMMERCIAL POLICY

> A full view having now been taken of the inducements to the promotion of manufactures in the United States, . . . it is proper, in the next place, to consider the means by which it may be effected.
>
> *Report on Manufactures*
> Alexander Hamilton
> December 5, 1791

A STRATEGIC PERSPECTIVE ON INDUSTRY can help us define an economy's industrial interests, analyze its postures in the world economy, and create a unified doctrine of access, trade, and development. Policy issues, from trade and investment to standards and patronage, can be so informed.

Trade. The primary and proper goal of American trade policy is to foster a world trading regime under which American producers can compete on an equal basis for access to commercial markets. This goal is far from being reached; it is generally won through close scrutiny of foreign markets and intense negotiations in cases where such markets are tilted toward the home team. Insofar as our negotiators are unlikely to get their way everywhere and at once (and insofar as we have our own trade barriers), we must establish priorities among targets. A strategic perspective is an essential prerequisite to setting such priorities. Simply put, it is more important to open up markets for strategic industries.

Trade policy must also recognize fundamental asymmetries in the institutional support given to companies that compete in world markets. In head-to-head competition with others, for instance, American firms can be forced to drop a line of business under short-term trade pressures. Meanwhile, the Japanese find ways to protect Japanese interests in a particular line of work regardless of how vigorously they are pressed. Outcomes of competition are thereby influenced by the strategic orientations of those who play. To accept the dictates of competition is to ignore the risk of having comparative advantage only in industries with weak growth and linkage prospects.

The more profound implications of trade policy may ultimately lie with the terms of trade on which America can gain technology. The Japanese, for instance, who hesitate to sell their technology for money, are willing to trade expertise for expertise (e.g., the Hitachi-Texas Instruments or Toshiba-Motorola semiconductor deals). But this willingness lasts only as long as America has something to swap. If we do not develop our own technology or are forced into lagging sectors, the wherewithal for such exchanges will be gone. Honeywell allied itself with NEC to boost its share of the Japanese market, but as it reached deeper into its supply of computer know-how, it ran short of things to give, and eventually threw its assets into a hybrid computer corporation with NEC and Bull.[139] America's loss of the leading edge in more sectors would leave it with fewer technologies to trade with and more competition in extracting bargaining value from those that remained.

That said, it is not necessarily in America's interest to get into every high-technology area. Consider DRAMs. After years of frustration with Japanese dumping, American trade negotiators won the right to set floor prices for them. Had American firms had a good chance to recapture market share, temporarily higher prices for imported DRAMs might have been worth it. But if not, America's interest lay in keeping DRAMs cheap, plentiful, and out of the control of competing computer manufacturers in Japan.

Instead, the trade agreement in DRAM's made MITI the industry's supervisor, letting it gauge production and ensure that no company could create a glut and start a price war.[140] The persistence of the 1988 DRAM shortage and its potential manipulation by Japanese computer companies can be linked to MITI's ability to control competition. Meanwhile, here, only TI and Micron make chips for the open market. TI usually introduces its best production technology in its Japan facility before bringing it to Texas. Two other producers are only now coming on line: Alliance, a start-up, and Motorola (with Toshiba technology); no volume production is expected in 1990 in either case.[141]

Sematech may exhibit better strategy. DRAMs are worth losing money on only when they give engineers practice with working ever-finer geometries (more complex chips delay production problems until design problems are solved). A research consortium dedicated to making memory chips offers that practice and allows it to be extended to other chips. At worst, it does not affect the market for memory chips; at best, it may persuade a few more American manufacturers to reenter the market and thereby keep competitive pressure on prices.

Standards. Standards govern the interaction of systems, particularly those that require data transfer to work. They are becoming the pivot of many critical technologies.[142] To set standards is to color industrial competition in areas ranging from HDTV[143] to smart buildings[144] and automobile parts management.[145]

The existence, creation, timing, and selection of standards involve difficult choices, though. Too many standards are as bad as no standards at all.[146] Late, vague, or incomplete standards leave too much work for systems integrators. Premature or overly comprehensive standards can stifle innovation and inhibit the fine tuning of systems. Standards that unify otherwise unrelated technologies, as Japan's TRON microprocessor seeks to do, can open up hitherto impossible new applications.[147]

Our Government's role in creating standards is housed, at least nominally, in the National Institute of Standards and Technology (the old National Bureau of Standards). The institute seeks to create a consensus among users and producers but has little authority and less desire to impose it. More often, standards are imposed de facto by powerful corporations.

In some sectors, however, Government can and does promulgate standards through its buying power. But Government standards based on peculiar needs may lack market sense if they pull suppliers from the commercial mainstream. Standards (and their adherents) succeed in the wider world when they offer competitive advantages to users relative to nonusers. The challenge, therefore, is to make the learning and adopting of standards into interesting problems. Those who master them should have a leg up in solving similar problems in the commercial world. It may be hard for Government to guess the next-generation problems when the market is only generating this-generation problems, but practice at doing so may yet pay off for the industrial technology base, even if errors are occasionally made.

The current debate over the HDTV industry has drawn attention to another, but less promising, aspect of standards. In this case, how the Federal Communications Commission (FCC) chooses to define a broadcast standard is said to influence the prospects for American companies to reenter the television industry. If the FCC chooses a new Japanese standard, American companies would be shut out; the choice of a new standard more compatible with current ones would give them a chance. It is probably useful to recognize standards as one arrow in our competitive quiver, but to choose standards explicitly on that basis invites retaliation. American negotiators, for instance, are hectoring Europeans to give us fair warning every time they change their telecommunications or medical equipment standards so that we can compete in their market.[148] Standards so set can be a trade barrier. It is more productive to choose standards for ourselves that are good problems on the assumption that American companies are, everything else being equal, more likely to take on such problems and learn from them.

Patronage. The French have devised a strategy of leveraging public expenditures to foster what they judge to be their strategic industries. In modernizing their railway system, they reserved equipment contracts for French suppliers and, by so doing, upgraded their rail-car industry as well.[149] The French commitment to nuclear power generation has allowed them to build nuclear reactors more cheaply than America and the other European Economic Community (EEC) countries because they build a lot of them.[150] France putatively has the most cost-effective telephone service in Europe, a Minitel messaging system, and the world's highest level of digitization; all this can be leveraged to win financial services business from London. Japan's chipmakers credit Nippon Telephone and Telegraph's (NTT) patronage for their current success more than they credit MITI's VLSI consortium.[151]

Government's patronage opportunities are not restricted to DOD. The General Services Administration (GSA) telecommunications contract could influence how American companies get into integrated systems digital network (ISDN) standards. FAA's contract to build advanced radar screens[152] could be used to buy continually larger display systems and thus help American manufacturers down the learning curves. Government influence can also be extended to directly regulated sectors (e.g., power and telephone companies) or indirectly regulated sectors (e.g., housing and health).

It may be useful to recognize such instruments when choosing intervention points in building a domestic HDTV industry. There are many sound reasons for wanting an American HDTV industry. Sales volume is likely to be large, and resolution of the lines-per-picture standards problem will ease the introduction of HDTV into the American market. One official of the American Electronics Association posits that losing half the domestic market in HDTV will portend losing 20 percent of the world market for personal computers.[153] But it is impossible to understand the linkage effects of HDTV without knowing what kinds of problems have to be solved before HDTV becomes a reality.

Are these problems the same as those that have to be solved for related industries? Are the linkages developmental? Would the fact that HDTV's contain great numbers of memory chips (albeit a slightly different kind than computers use) be sufficient to reestablish the American industry? America's current requirement for two-thirds of the world's memory chips has not prevented the Japanese from supplying 90 percent of the world market. Conversely, American firms dominate the market for graphics card and software drivers, even though they do not make displays. Given that most computer screens are already imported, would the loss of the HDTV market presage loss of the computer market through its use of other common technologies? Knowing only that there are links between sectors is not sufficient. What matters is the method and extent to which these links carry interesting problems, and how solutions to these problems will be used.

By contrast, increasing requirements for flat computer screens, the military share of which is projected to reach

$500 million by the next decade, poses a rich challenge and one which can benefit directly from directed patronage.[154] Japanese firms now dominate the industry and its linkages.[155] Indeed, most of the world's computers with flat screens are made in Japan, even some with American names.

Normally, Government would choose between buying displays overseas or favoring a coterie of domestic producers willing to work military specifications. The former option gives Government little influence over the development of technology; the latter restores its influence but at a stiff price. A third option exists: develop a dual-use industry here. Government would thereby enjoy lower costs (through economies of scale), increased competition (larger markets attract more players), and accelerated innovation (industry is responding to a multiplicity of stimuli). In exercising this option, Government can build on a vigorous start-up industry, representing the three competing technologies of liquid crystal display (LCD), electroluminescence (EL), and gas plasma.[156]

Japanese display vendors have already targeted this market as strategic and have set up a national project to develop and build displays.[157] Nevertheless, American companies may have the advantage, at least for now, in their display technology.

Regaining the lead from the Japanese is possible, even in electronics. It was the Japanese who initially opened up the microcomputer graphics chip market that TI and Intel now dominate. TI's 34010 chip was the first of a new generation of integrated graphics chips. Intel's 82786 chip garnered the support of many software companies.[158] American producers had nearly been driven out of the Winchester hard-disk-drive business by Fujitsu and Hitachi, but leaped onto thin-film technology early and hard and now hold roughly three-quarters of the world market; they now lead by 2 years in design and technology.[159]

Foreign Direct Investment. The rapid increase in the number of foreign-owned (transnational) facilities here has generated considerable unease (despite the fact that American companies have been doing the same overseas for far longer). Part of the unease is irrational in that many of the same people who argue that America is harmed by foreign ownership are equally troubled when American firms invest overseas rather than at home. Other countries' multinationals may, in fact, be different, but this must be explicitly shown.

To gauge the static value of a transnational facility, we must know how it affects the distribution of value added (the breakdown of price by source). Assume, typically, that half of a product's value added comes from purchased parts; the rest is split equally among white-collar workers, blue-collar workers, purchased services, distribution, and returns to capital.[160] Imports leave 10 percent of their value here, mainly distribution costs. The initial step in multinationalization is often just simple assembly, which relocates only work-force labor, some professional labor, and some purchased services. Seventy percent of the value added is still imported. It takes buying parts and services locally, and transferring management and research, to get the value added originating from overseas toward 10 percent.

The dynamic value of a transnational facility depends on its intercorporate status and the linkages it is allowed to make. Will headquarters, for instance, allow the best technology to leave the home country? Will the facility get its own or even headquarters' problems to solve or will it be the passive recipient of solutions generated elsewhere? If it becomes more competitive, will it be allowed to grow at the expense of home-country sites?

To date, linkages from new transnational facilities have been mixed. Japanese automakers first used their American operations to assemble Japanese-made parts. They now project that local content will rise from just over half to nearly two-thirds by the next decade, but to nowhere near domestic levels of 90 percent.[161]

Domestic suppliers can often benefit from selling to Japanese firms, whose just-in-time inventory management and design requirements get suppliers to invest in new equipment to win a contract. Americans who learn to deal with them are well rewarded by learning how to compete internationally while still at home. Some think they can seize new opportunities to export to Japan.[162] Too many of these challenges, however, have gone to the transnational facilities of Japanese subcontractors instead, vitiating some of the linkage potential. Similar statements can be made for linkages to local services.

Work-force linkages could be substantial if the new owners introduced new production techniques and management skills.[163] Whether workers continue to develop, again, depends on the problem-solving role of the transnational facility within the larger organization. A low-skill, screwdriver operation creates few good links. A research-oriented facility that rewards skills and education motivates investment in human capital.

Worries that America may be losing control over its best technologies also stem from the vulnerability of capital-starved companies to overseas investors.[164] There is much less reverse flow; overseas technology is more often locked into large, stable, or protected corporations. The sale of a company, though, does not make it available for giftwrapping and shipping.[165] Most purchasers want to participate in the American market and maintain the organization that created the coveted technology in the first place. A strategic perspective would therefore judge the sale by how it alters the linkages between the affected firm and rest of the world, and the resulting parity in the flow of information along the linkages.

Conclusion. A strategic perspective on an industry's development is a useful input to decisions that affect its fate. Such perspective is best considered a supplement to rather than a substitute for other modes of analysis such as legal or benefit cost. Yet, perspective alone does not constitute the industrial strategy that America may need to retain its status in a world where our competitors have so profited from theirs.

VII. NATIONAL STAKES IN THE GLOBALIZATION OF INDUSTRY

Everything tending to establish substantial and permanent order in the affairs of a country, to increase the total mass of industry and opulence, is ultimately beneficial to every part of it.

Report on Manufactures
Alexander Hamilton
December 5, 1791

THE PRIMARY DIFFICULTY in coming to grips with the national security dimensions of industrial development is that of identifying both the players and the stakes. Clearly, national governments and national work forces are players with, in certain cases, antithetical interests. But the key decisionmakers in the world economy are multinational corporations, whose interests transcend national boundaries. Nor is it obvious that the enrichment of others threatens us, particularly when the "threat" comes from military allies who have recognizable political systems.

The Players. By now most of the world's competition in manufactured goods is carried on by multinational corporations with various degrees of affiliation with the home country. Twenty percent of the free world's value added in goods is provided by 600 multinationals; American companies among them employ 6.5 million people overseas.[166]

IBM may be considered a prototypical example of the low relationship between home and headquarters. In Japan, it strives to be more Japanese than the Japanese and has achieved a major "insider" position.[167] In Europe, Jacques Delors, an EEC official, concedes, "For us, IBM is a European company."[168] Its latest Nobel prize was won by its Swiss researchers. IBM favors America only through its defense work, its support of Sematech, and its allocation of R&D and management slots.

The decreased correlation between a producer's home and its value added pervades other industries. Siemens, Europe's largest electronics firm, expects to be a net exporter from the United States in 1989.[169] Indeed, domestic subsidiaries of foreign companies are expected to account for as much as

8 percent of America's exports of manufactured goods.[170] The domestic content of Boeing aircraft can be as low as 70 percent if Rolls-Royce engines are specified, while some versions of the Airbus have almost as much American as European content.[171] The world's largest oil-field services company, Schlumberger, is French owned, headquartered in New York, chartered in Aruba, and stationed wherever oil is sought.

The spreading of corporations across national borders makes it difficult to ensure that the benefits of helping a corporation will remain at home.[172] By the same token, a country does not need a national "hero" in order to participate in technological progress.[173] These factors suggest that industrial strategy should concern itself less with building corporations and more with building industrial networks.

Yet, a company's home is still relevant. Asian companies, small firms, and those whose governments provide a large share of their ownership or sales are more likely to have a strong home orientation. The terms of trade among nations and regions depend, to some extent, on who comes from where. Nor does the multinationalization of a nation's industries mean that they are no longer an instrument of national strategy. Siting production overseas, may, in fact, be just one more stage in fostering a division of labor that favors the home country; Japan is an example.

Japan first fostered leading-edge sectors by restricting high-technology imports and transnational facilities long enough for domestic firms to realize economies of scale and experience. The Japanese Government helped via implicit loan guarantees for industrial investment (to support the taking of major technological risks), joint research projects (to lower the costs of basic research), and recession cartels (to retire capacity and avoid profit-sapping price wars).

Having filled domestic needs, patient Japanese firms entered world markets by exploiting transient market opportunities, such as the opening for small cars prompted by the oil embargo, or the failure of American companies to meet demand after cutting back investment in a prior recession (e.g., steel, chips). Japanese companies succeeded because they could withstand failures while waiting for their opportunity. Witness their yet-to-be-successful attempts to sell America personal computers.

Superior market position won them both scale and learning-curve economies while financial backing allowed them to invest through price wars. Japanese firms also got new generations of product to market faster than American firms: 50 versus 70 months in automobiles,[174] or 2.3 versus 2.8 years for every new generation of DRAMs.[175] Since the ability to generate the next generation can piggyback on the current ones, shortening the product cycle offers cumulative advantages.

Japanese firms are now turning to multinationalization. They locked in temporary competitive advantages by establishing joint ventures. To co-opt competing technological thrusts, they persuaded Western firms to market Japanese products instead of building their own. Putting facilities into export markets also helped develop overseas vertical linkages and discourage hostile commercial and political alliances. Japanese investments here also created new markets for Japanese suppliers of parts and equipment (e.g., computers). Almost half of Japan's foreign direct investment returns home as machinery exports.[176]

Japanese investments that give them more of the American market furthered the international division of labor, which is to say the international division of interesting challenges. While the Mazda facility in Flat Rock put assembly jobs in Michigan, it left the manufacturing of complex parts and production equipment in Japan.[177] Honda, for its part, is starting to make engines in the United States, but its plan calls only for producing the low-technology portion while home plants keep the more interesting part.[178] The home plants get to solve problems that are technologically more difficult and rewarding than those that American parts vendors or assembly workers get to solve. Manufacturers who meet interesting challenges not only improve their technology faster but are in a better position to receive the next generation of challenges. Thus, the Japanese production base becomes even more impervious to challenge. (At the same time, many American corporations have found that their Japanese subsidiaries prefer to buy from Japan rather than from them.[179])

It can be expected that Japanese companies that have overcome competition will not want to sell their technology (except in declining sectors). As other multinational corporations have become more reluctant to sell technology in reaction, Japanese firms have resorted to trading like for like. The better the technology the Japanese have, the less of it they have to give up in trade for the technology of others. Keeping rivals from using their technology because they lack the links to other sectors allows the Japanese to trade that much more easily. Thereafter, technology leaves Japan only through transnational facilities, and then it is not always the best. Sony makes all its Walkmans, Trinitron cathode-ray tube (CRT) guns, and Super-Video Home Systems in Japan. Although Japanese Victor Corporation (JVC) makes 60 percent of the VCR's that it sells in Europe, the crucial high-precision component, the spinning tape head, invariably comes from Japan. All these technologies will eventually be shifted abroad—but not until the factories now producing them are needed for future marvels such as flat-screen televisions.[180]

It now matters whether Japanese firms are corporate agents of the nation or independent entities with motivations similar to American ones. Fujitsu's attempt to buy Fairchild Semiconductor was opposed by American officials who feared that the Japanese firm would drain Fairchild of its unique technology and leave behind a carcass.

On one hand, the formal ties that bind Japanese companies to their government have loosened. MITI used to broker corporate marriages; it created Nippon Steel by combining Fuji and Yawata. The Finance Ministry used to put subtle pressure on banks to finance industry. But as corporations have grown in size, wealth, and strength, the Japanese Government's need and ability to carry out such policies waned.[181] Now that Japan needs fewer technology imports, MITI's control over such trade has become moot. MITI still works on Japan's technology strategy, but more as a catalyst than as a driver.

On the other hand, Japanese multinationals are still linked back home through key research facilities (particularly through NTT, Japan's phone company), finances (from insurance companies, banks, and cross-holdings), suppliers, and culture, particularly the sense of being different. As late as 1986, Japanese firms did only 4 percent of their production abroad, versus 17 percent for U.S. firms and 20 percent for German ones.[182] On one index of comparative multinationalization, Japanese firms scored 2.75 in 1978 and 2.85 in 1985, with the aim of reaching 3.3 this century, compared with 4.1 for Western firms.[183] A recent MITI survey found that 45 percent of top officials at Japanese-owned subsidiaries had been transferred from home, versus 17 percent for foreign-owned subsidiaries in Japan. Japanese firms overseas borrowed only a quarter of their funds from indigenous banks versus 70 percent for foreign firms in Japan.[184]

Even those Japanese firms known to be independent of MITI and the keiretsu—Sony, Honda, Kyocera, Matsushita—concentrate their research at home. Kyocera, despite its large San Diego facility, confines its pure research to Japan, limiting San Diego to production support.[185] Sony keeps 90 percent of its engineers in Japan; Matsushita, 99 percent.[186]

So, while the Japanese multinationals may turn out to be just like ITT, Shell, or Nestlé, evidence to that effect remains slow in coming.

The Stakes. The 20th century opened in an era of imperialism, whose method of control was military and whose medium of exchange was economic. Trade followed the flag. America's focus was on internal development, and against its will it was forced onto the world stage. By the middle of the century, it has at last grown comfortable with its role. It used its position to foster compatible ideologies of democracy, freedom, and capitalism, first through the recovering developed world and then through the developing nations. With rare exceptions, it did so selflessly and with a fair amount of success.[187]

And now? Opinions differ on whether economic indicators portend a permanent shift in the world balance of power. Sam Huntington writes:

> In contrast to other countries, the United States ranks extraordinarily high in almost all the major sources of national power: population size and education, natural resources, economic development, social cohesion, political stability, military strength, ideological appeal, diplomatic alliances, technological achievement. It is, consequently, able to sustain reverses in any one area while maintaining its overall influence stemming from other sources.[188]

While, Felix Rohatyn worries that—

> At a time when both superpowers have implicitly recognized the irrelevance of nuclear weapons (except as a deterrent) the real power in the world is coming to consist of surplus capital combined with national self-discipline, advanced technology and superior education. The leading nations of tomorrow, by those standards, are likely to be Japan and post-1992 Western Europe.[189]

But what if the course of empire no longer runs from economic power to political power and vice versa? What if, in the words of the *Economist,* technology and not dominion has become the direct measure of a country's power?[190] Is there a different way to find the essence and purpose of empire?

Consider America's competition with a new constellation of economic power, centered in Japan with close extensions to South Korea, Taiwan, Hong Kong and Shenzhen, Singapore, Malaysia, and Thailand, and far extensions to Indonesia, the Philippines, other coastal Chinese provinces, Siberia, Australia, New Zealand, and Hawaii.[191] Japan has recently formed a high-powered committee to explore a consensus on what form its regional trading bloc should take. Asian economies are becoming horizontally integrated; the newly industrialized countries assemble Japanese-supplied parts and serve as proxy exporters for Japan to America.[192]

Unlike the nascent European bloc, the Asian bloc has neither political structure nor bonds of mutual amity. It is being drawn together by a compelling economic logic, undergirded by increasing flows of business sponsored by Japanese multinational corporations.

Is there a national security threat here? Will the century close with a new era of imperialism whose method of control is economic and whose medium of exchange is technologic?

By conventional measures, such fears are groundless. Japan is our military ally and will probably remain so in the face of Soviet military power. It disdains nuclear weapons; even if it changes its mind, it would take 25 years to develop them, together with a survivable launch system such as submarines.

The Japanese feel little need to convert anyone to their own ideology. Indeed, their primary belief is not in the universality of their experience but in the particularity of their nation.[193]

Yet, a Japanese empire built from economic power may affect our well-being by restricting or channeling the way technology develops. It will influence who learns to work the new technology and indeed how this technology is to work.

To control the developmental links is to control the dissemination of interesting questions, challenges, and opportunities. The core keeps the good questions for itself, learns faster, and releases the results to its own advantage. If someone outside comes up with a good idea, the path between idea and market has to proceed through the core, because the institutional structure to develop a technology externally does not exist. What would otherwise be good solutions are co-opted or left to wither. Once or twice, challenges may be solved outside, but the longer range development of the technology will be kept at home.

A world dominated by the momentum of Japanese technological development is one in which the developmental linkages flow from other countries to Japan rather than being more evenly distributed. An analogy may be found in railroad networks of the 19th century. In Latin America, Africa, or Australia, they ran from the interior to the coast, linked to ports that connected them to Europe. Networks that come together only in other countries inhibit the formation or retention of institutions that can integrate technologies into systems and make it difficult to come together to preempt the concerted strategies of others. Outsiders' contributions are then valued only for what they can immediately command.

The paths by which technology is developed are closely related to the distribution of techno-economic power. Standards are one example; the formation of a dominant standard, such as machine-control software, forces research into compatible technologies. The aforementioned difficulty of getting Japanese technology developed to military requirements is another example. More broadly, imagine two alternative paths for computers. One promotes increasingly specialized and intensive electronics development (a Japanese specialty); the other promotes generalized systems differentiated by software (an American one). Both electronics and software develop, but at some point a choice must be made. Perhaps designs might have been able to accommodate moves in either direction; but with the dominance of electronics, many innovations in software are precluded. Major changes from one to the other realm are too risky. Meanwhile, the infrastructure that supports electronics innovation rises in importance while the comparably capable infrastructure that supports software innovation declines.

The influence of technology on power outside military channels is a force that must be recognized to be mastered. It is fair to say that American policy and American institutions promoted the diffusion of opportunity when their technology was dominant. The new task is to ensure that the same remains true in the face of overseas challenge.

Strategy Is Perspective. In America, industrial strategy creates perspectives, not plans, because its economy is not very well organized (nor should it be) for top-down control. We lack the Soviet command structure, the Japanese consensus process, or the German cartel arrangements. We have, instead, the world's best-distributed information-processing network, and we should use it as such.

Like Japan, America needs to see itself as building an infrastructure of information. Ignorc glib suggestions that we take the software end while Japan takes the hardware end. The two are linked, and Japan has an enormous capacity to collect information. Rather, we ought to ensure that our ability to receive interesting questions and generate interesting answers to them remains the basis of our prosperity and military strength.

Industrial strategy therefore concentrates on keeping our economy open. We have to be open to foreign influences and challenges; if they come via the multinationalization of foreign enterprises, so be it. But we must simultaneously ensure that our openness does not allow others to control the interesting questions before they get to us.

NOTES

[1] See, for example, *Economist,* 14 January 1989, 65, on what the Dutch consider strategic.

[2] *Economist,* 27 February 1988, 15, asserted, "It is not the American ownership of GM that is of worth to America; it is the jobs and investment and access to technology that GM manages to provide. The only long-term guarantee here is the rightness of its business decisions—and this might be as solidly delivered by Japanese management as by the bosses of Detroit."

See also *Economist,* 14 January 1989, 85.

[3] Two good sources for such data are U.S. Congress, Office of Technology Assessment, *Paying the Bill: Manufacturing and America's Trade Deficit.* OTA-ITE-390 (Washington, D.C.: GPO, June 1988), and vol. III, *Working Papers of the President's Commission on Industrial Competitiveness (the Young Commission), Global Competition, the New Reality* (8 November 1984) (reprinted as BRIE Working Paper #8, University of California, Berkeley).

[4] *Economist,* 9 September 1988, 64. See also National Science Foundation, *Science and Technology Data Book, 1989.* As of mid-decade (by year of application), American firms were being granted 35,000 patents a year as opposed to 30,000 to foreign firms. In 1970 the breakdown was 45,000 to 20,000.

[5] Data from a forthcoming Department of Commerce report on electronics, as previewed by Robert Cohen in a briefing to the Defense Manufacturing Board, 7 March 1989.

[6] Fred Bergsten, *America in the World Economy* (Institute of International Economics), 1988, 4.

[7] *Economist,* 6 February 1988, 64.

[8] In its FY 1986 defense trade with Memorandum of Understanding (MOU) countries, America exported $5.5 billion and imported $3.1 billion for a ratio of 1.75 to 1. When the not fully developed countries (Egypt, Portugal, Turkey, Greece, and Spain) are subtracted, the ratio stands at $3.8 billion to $3.0 billion or 1.25 to 1. Source: Office of Management and Budget, *Impact of Offsets in Defense-Related Exports: A Summary of the First Three Annual Reports* (Washington D.C.: GPO, 1987).

[9] For submarines, see *Defense News,* 20 March 1989, 1, and for armor, see *Defense News,* 18 April 1988, 18, and for aeronautics, note the current inability of any American aircraft to duplicate the angle-of-attack features of the Su-27. See *Aviation Week and Space Technology,* 14 August 1989, 54.

[10] Source: Defense Intelligence Agency. Cited in Bruce D. Berkowitz, "Reviving Defense R&D," *Issues in Science and Technology* (Winter 1988-1989): 53-60.

[11] *Economist,* 10 December 1988, 68.

[12] Dr. French of North American Philips Co., quoted in *Electronics,* March 1989, 70.

[13] Stephen S. Cohen, and John Zysman, *Manufacturing Matters: The Myth of the Post-Industrial Economy* (New York: Basic Books Inc., 1987) 102-106. See also Nathan Rosenberg, *Inside the Black Box, Technology and Economics* (Cambridge: Cambridge, 1982).

[14] *Ibid.,* 101, regarding Peter S. J. Dunnett, *The Decline of the British Motor Industry* (London: Croon Helm, 1980).

[15] Martin C. Libicki, Jack Nunn, and William Taylor, *US Industrial Base, Dependence/Vulnerability: Phase II—Analysis,* MCDC Report, (Washington, D.C.: National Defense University, 1987), 37-50.

[16] Clyde Prestowitz said in *Business Week,* 18 September 1986, 63, "By the early 1990s the Japanese will dominate every segment of the [chip] market worldwide—with the possible exception of a few custom chipmakers. Nothing American industry can do will stop them."

Also, Charles Ferguson said (*Business Week,* 20 April 1987, 62), "If nothing substantial changes, the U.S. semiconductor industry will be gone in five years."

[17] *Electronics,* 8 January 1987, 103.

[18] U.S. Congress, Office of Technology Assessment, *The Defense Technology Base: Introduction and Overview—A Special Report,* OTA-ISC-374. (Washington, D.C.: GPO, March 1988), 16.

[19] *Electronics,* 30 October 1986, 59

[20] *Electronics,* 26 May 1986, 48; and *Business Week,* 9 March 1987, 104.

[21] Office of Technology Assessment (OTA), *The Defense Technology Base,* 15.

[22] Michael L. Dertouzos, Richard K. Lester, Robert M. Solow, and the MIT Commission on Industrial Productivity, *Made in America: Regaining the Productive Edge* (Cambridge: The MIT Press, 1989), 223.

[23] Quoted in the *New York Times,* 3 March 1989, Dlff. *Business Week,* 29 May 1989, 111, noted, "New Japanese chip equipment tends to be available to Japanese customers six months or more ahead of overseas companies. In the frenetic semiconductor game, six months can be a disastrous delay."

[24] Prudential-Bache, *High Tech Notes,* 1988.

[25] Author's conversation with corporate officials, 15 June 1987.

[26] *Electronics,* 10 March 1986, 44.

[27] Cray recently spun off its founder, Seymour Cray, and his development project, the Cray-3, in the wake of CDC/ETA's demise. See *Business Week,* 29 May 1989, 31.

[28] *Business Week,* 23 March 1987, 116A.

[29] *Electronics,* 3 March 1988, 57.

[30] *Electronics,* 3 March 1988, 34.

[31] Author's conversation with Fujitsu officials at Atsugi, Japan, laboratory, 18 September 1986.

[32] *Business Week,* 20 February 1989, 137.

[33] *Economist,* 1 October 1988, 81.

[34] *Business Week,* 30 January 1989, 65.

[35] *Electronics,* March 1989, 117.

[36] *Business Week,* 8 June 1987, 133; 25 June 1984, 108H.

[37] *Electronics,* April 1989, 42.

[38] *Economist,* 12 December 1987, 76.

[39] Alan M. Wolsky, Robert F. Giese, and Edward J. Daniels, "The New Superconductors: Prospects for Applications," *Scientific American* (February 1989), 61-69.

[40] *Business Week,* 31 August 1987, 63, stated "Japan's leading superconductivity expert says that the first application of room-temperature superconductors will probably come in toys."

[41] Let us assume that Greece has no inflation, and that Spain has a 10-percent inflation. Everything else being equal, the Greek drachma will be expected to appreciate against the Spanish peseta by 10 percent a year. This does not mean that Greece is more successful in international trade. The price of Spanish olives would rise from 100 to 110 pesetas over a year; the price of Greek olives will hold steady at 120 drachmas but each drachma is worth 10 percent more in pesetas.

[42] Cohen and Zysman, *Manufacturing Matters,* 105.

[43] The president of Sony recently remarked (as quoted in *Economist,* 13 March 1989, 31) that Americans still imagine [Japan's trade surplus] to be based on sales of price-sensitive Jap consumer goods; in fact it was now driven by irreplaceably sophisticated Japanese capital equipment.

[44] Sony's strategy is reported in *Business Week,* 1 June 1987, 55; Matsushita's strategy in *Business Week,* 30 December 1985, 62.

[45] *Business Week,* 9 July 1984, 103.

[46] *Economist,* 4 March 1989, 61.

[47] *Economist,* 25 February 1989, 64, said, "For a breed once thought to be facing extinction West Germany's mechanical engineers' order books are bursting and exports booming especially to Western Europe. West Germany's trade surplus this year [looks to be] even higher than the record $73B of 1988. Capital goods account for more than half of total exports and their share is rising."

[48] Cohen and Zysman, *Manufacturing Matters,* 241.

[49] *Economist,* 4 February 1989, 13.

[50] The argument is threefold:

Take two industries, A, a $10 billion purchaser of parts, and B, a $1 billion purchaser. Everything else being equal, A will buy 10 times as much as B and its links would thus be 10 times larger. But to argue that A was that much more strategic falls prey to a meaningless redefinition of B that is created by aggregating it with similar industries to make it larger.

Take two industries, A, which buys $100 million worth of parts from each of 10 industries, and B, which buys $1 billion worth from only 1 industry. Everything else being equal, A's fate affects more industries but only by a tenth as much. The increased width of its links is matched by its decreased individual impact.

Take two industries: A buys half of its parts from industry C, and the other half from all the rest; B also buys half its parts from industry D. A then buys out C over time. Does this action make A any more or less strategic? The argument that it does only works if C's access to what used to be its customers is curtailed.

[51] From statistics generated by Paine Webber and the American Iron and Steel Institute as cited in *Economist,* 17 December 1988, 75.

[52] *Economist,* 19 March 1988, 67.

[53] *Economist,* 17 December 1988, 75.

[54] *Economist,* 19 December 1987, 57.

[55] Probably. See *Business Week,* 30 November 1987, 108B.

[56] Dertouzos, in *Made in America,* said, "Our machine-tool study group concluded that the lack of user demand for innovative products has been a key contributor to the decline of the U.S. machine tool industry, as well as to the users' own lack of competitiveness in international markets." (p. 100)

"Our study of the textile industry showed how Japanese textile firms have taken advantage of close interfirm linkages to reduce inventory, cut down on order time, provide feedback about consumer preferences and introduce new product and process technologies. In Germany and Italy too, informal and contractual relationships between firms at different points in the textile complex have been a key source of competitive advantage." (p. 101)

"Strong customer demand for technological advances was a key factor underlying the long-term risk-taking attitude of aircraft manufacturers." (p. 104)

[57] Eric von Hippel, *The Sources of Innovation* (New York: Oxford University Press, 1988), 4, table 1-1.

[58] *Business Week,* 10 April 1989, 62. The four that do are 3M, Dow-Corning, General Electric, and Black and Decker. The four that did not have that factor specifically mentioned (but might do so anyway) are Rubbermaid, Hewlett-Packard, Merck, and Johnson & Johnson.

[59] Statement by Victor DeDios of Dataquest in *Electronics,* 5 February 1987, 65. Echoed by Dan Klesken of Montgomery Securities in *Business Week,* 2 April 1984, 71, who held "geography" and "language" to be key to developing specialized memory chips for computer customers.

[60] *Metalworking News,* 2 May 1988, 5.

[61] In the "Survey of the Motor Industry," *Economist,* 15 October 1988, 23, stated, "The greater dependence on component suppliers by carmakers has far-reaching consequences. Component companies are now getting involved in new products from their conception. What do the component companies get in return for their extra efforts? A bigger, and perhaps exclusive, share of a carmaker's business and longer-term contracts. This shift in the business is known as single sourcing. Throughout the industry, carmakers are reducing their number of component suppliers, often by half. As cars, and the bits that go into them, get more sophisticated, carmakers and component technologies are also helping each other out with new technology."

[62] General Electric's Appliance Park complex had 1,400 vendors in 1986, down to 850 in 1987 and shooting for 200 in 1993, as reported in *Metalworking News,* 13 March 1989, 4. For Motorola's example, see *Fortune,* 24 April 1989, 157. For Xerox see *Business Week,* 19 September 1988, 105.

[63] At present, roughly 250 Japanese firms make car parts in the United States, a tenfold increase from 1980 (*Economist,* 8 April 1989, 79). Yet, of the 126 U.S. auto suppliers that have entered into joint ventures to supply Honda, Nissan, and Mazda, almost all are losing money, and Japanese suppliers hold 20 percent of the $40 billion U.S. auto-parts market (*Business Week,* 24 July 1989, 30).

[64] *Economist,* 12 December 1987, 76.

[65] As an example of how business services make urban areas attractive, *Electronics* (April 1989, 8) cites Francis Kramer, president

of II IV Corp., a laser manufacturer. He lists, among Pittsburgh's infrastructure advantages, advanced testing laboratories and a full line of professional services from attorneys to accountants.

[66] See the *Business Week* article, 10 July 1989, 56-62.

[67] Quoted in *Business Week,* 12 September 1988, 75.

[68] According to *Economist,* 12 August 1989, 57, Hewlett-Packard has become a large spinner of webs with which to take on IBM. CEO John Young just concluded a deal with Samsung to make low-cost workstations. This deal follows similar arrangements with Hitachi (chips), Canon (printer engines), Yokogama (instrumentation), Northern Telecom (microprocessors), Sony (digital audio tape), and Arthur Anderson (computer-integration manufacturing integration).

[69] As quoted by Tom Peters, 21.

[70] Kennichi Ohmae, "The Global Logic of Strategic Alliances," *Harvard Business Review,* 2(1989): 153.

[71] Suzanne Berger, Michael Dertouzos, Richard K. Lester, Robert M. Solow, and Lester Thurow, "Toward a New Industrial America," *Scientific American* (June 1989, 39-47), as extracted from Dertouzos, *Made in America.* The other four were outdated strategies, the lagging technological investment, difficult Government-industry relations, and short time horizons.

[72] *Economist,* 4 April 1988, 51.

[73] *Economist,* 21 January 1989, 67, stated, "From 1972 to 1982, according to Mr. Bo Carlsson (Case Western Reserve University), the value added by the average American firm to its shipments has fallen in 88 of the 106 sectors of metal-working industries."

[74] Charles H. Ferguson, "From the People Who Brought You Voodoo Economics," *Harvard Business Review,* 3:1988, 55-62.

[75] George Gilder, "The Revitalization of Everything: The Law of the Microcosm." *Harvard Business Review,* 2:1988, 49-61.

[76] "List of America's Top Fifty Exporters." *Fortune,* 18 July 1988, 71.

[77] See *Business Week,* 19 September 1988, 148, and *Business Week,* 19 February 1988, 70.

[78] For Tektronix, see *Business Week,* 12 December 1983, 126D. For Control Data, see *Economist,* 24 December 1983, 70.

[79] Tom Peters, "New Products, New Markets, New Competition, New Thinking," *Economist,* 4 March 1989, 21.

[80] Kennichi Ohmae, *Global Logic,* p. 143.

[81] *Business Week,* 7 March 1989, 94 said, "For every dollar of revenues that Apple generates, the outside network of companies that depend on Apple produce at least three to four dollars in

additional sales. . . . Like the best-managed U.S. concerns, the better-run Japanese companies are largely a collection of hundreds of individual companies."

[82] *Economist,* 21 May 1988, 21.

[83] For a view that no gateway technologies exist, see *Economist,* 1 April 1989, 17, which said, "Today's successful innovation is a complex blending of skills, best described as technological fusion. Japan's microchip industry gained preeminence only after fusing the know-how of camera makers (who developed new ways of printing microcircuits) with that of crystallographers (who perfected the purest of silicon wafers) with that of builders (who had learned to make rooms dust-free). The line of innovation has curled into many circles. No longer does control of access to one bit of technology necessarily check the progress of others."

In contrast to the *Economist's* argument, it is equally likely that the very multiplicity of enabling technologies makes it more likely that any one of these could be a gateway technology. Consider what would happen to America's international competition in microchips, if Nikon and Canon wrest a collective monopoly position in optical steppers and then refuse to sell any to American customers until years after they were offered to Japanese competitors.

[84] *Business Week,* 28 November 1988, 132f.

[85] *Economist,* 19 November 1988, 75.

[86] *Economist,* 4 February 1989, 68. To head off potential antitrust problems, though, they sold half to Delta. American Airline's CEO observed that "Sabre is still ahead but nowhere nearly so far ahead as it was ten years ago" (*Business Week,* 20 February 1989, 55).

[87] *Economist,* 4 March 1989, 67.

[88] Von Hippel, *Sources of Innovation,* 4.

[89] *Metalworking News,* 13 February 1989, 4.

[90] *Business Week,* 30 June 1980, 121.

[91] See "Survey of Biotechnology" (*Economist,* 30 April 1988, 12), which said, "The Freedonia Group of Cleveland, Ohio reckons that sales in America of biotechnology-related agricultural products will exceed an annual $100 billion (at today's prices) by the turn of the century."

[92] *Economist,* 13 February 1988, 62. See also *Economist,* 15 October 1988, 84, for British examples; *Economist,* 25 June 1988, 70, for Japanese examples; and *Economist,* 19 March 1988, 75, for Italian ones. See also *Business Week,* 7 November 1988, 116, and

U.S. Congress, Office of Technology Assessment, *The U.S. Textile and Apparel Industry: A Revolution in Progress—Special Report.* OTA TET-332 (Washington, D.C.: GPO, April 1987).

[93] "Annual Petrochemical Report," *Oil and Gas Journal,* 5 September 1988, 33-42.

[94] Biotechnology firms underestimated the time it would take to get their products approved. *Economist,* 13 May 1989, 69, asserted, "At first they predicted that their products would rush through drug-approval systems because they were similar to naturally occurring substances. Now, it is clear that the FDA has decided to treat biotechnology products as conventional drugs. In some cases, such as growth factors, the FDA is demanding even more stringent testing."

[95] As one student in a high school remedial mathematics class informed me, I was foolish to go to college when I could stay home and earn good money making cars.

[96] For machine tools, see *Business Week,* 6 December 1982, 63; for robots, see *Business Week,* 22 December 1986, 45.

[97] See *Business Week,* 17 February 1986, 94B regarding four-wheel steering.

See *Economist,* 4 September 1987, 63 regarding map displays.

See U.S. Congress, Office of Technology Assessment, *New Structural Materials Technologies: Opportunities for the Use of Advanced Ceramics and Composites—A Technical Memorandum,* OTA-TM-E-32 (Washington, D.C.: GPO, 1986), 30-33 regarding ceramic engine parts.

See *Economist,* 21 November 1987, 92 regarding active suspension.

See *Business Week* on four-wheel steering, and the *Wall Street Journal,* 23 May 1989, 1, regarding multivalve engines.

[98] *Economist,* 19 December 1987, 57.

[99] While American producers have maintained their 70-percent share of the domestic market over the past 5 years, their share of the Japanese market has fallen from 80 percent 10 years ago to 14 percent last year. America's share of the rest of the world fell from 63 percent to 49 percent over the last 5 years. Data from VLSI Research's Hutcheson as cited in *Electronics,* August 1989, 62.

[100] *Economist,* 8 August 1987, 55.

[101] As Professor Les Thurow noted, one can do worse than by copying the Japanese (*Business Week,* 4 July 1983, 61), who are, as often as not, getting their cues from Wall Street. Clyde Prestowitz argues that it is not necessary to pick winners; everyone knows who they are. The point is to promote them.

[102] The classic example comes from the history of the integrated circuit industry. Production increased while prices dropped and the composition of demand shifted away from DOD.

Year	Production ($ million)	Price ($/per)	Defense Demand (percentage)
1962	4	50.00	100
1963	16	31.00	94
1964	41	18.50	85
1965	79	8.33	72
1966	148	5.05	53
1967	228	3.32	43
1968	312	2.33	37

Source: John Tilton, *The International Diffusion of Technology: The Case of Semiconductors* (Washington, D.C.: The Brookings Institution, 1971), 91, Tables 4-8. As quoted from Michael G. Borrus, *Competing for Control: America's Stake in Microelectronics* (Cambridge: Ballinger, 1988), 72.

[103] For more detailed discussions of the subject, see U.S. Congress, Office of Technology Assessment, *Holding the Edge: Maintaining the Defense Technology Base,* OTA-ISC-420 (Washington, D.C.: GPO, April 1989); and Jacques Gansler, *Affording Defense* (Cambridge: MIT Press, 1989).

[104] *Electronics,* July 1988, 67, said, "[Those skeptical that defense technology can be adapted to commercial markets cite] Litton's abortive attempt to bring aerospace design to the shipbuilding industry in the 1960s. And then there was Ford's inability to leverage technology for its aerospace until the 1970s. Some also pointed to TRW's failure to convince automakers to use its expensive solid-state power steering which used technology related to TRW's military electronics business."

[105] One example, typical of many, from *Business Week,* 4 July 1983, 78B.

[106] *Business Week,* 23 January 1989, 35.

[107] These data come from a proprietary data base that identifies the primary subcontractors on precision-guided munitions, and their salient production characteristics. For a larger discussion, see chapter 4 of Martin C. Libicki, *Industrial Strength Defense,* distributed by the Strategic Capabilities Assessment Center, National Defense University.

[108] Estimate as of early 1987. Data derived from *Status 1987: A Report on the Integrated Circuit Industry,* (Scottsdale Ariz.: Integrated Circuit Engineering Corporation), as well as the DOD-proprietary data base referred to before.

[109]Arguments have been made against DOD patronage. Without a strong dual-use focus, it can reorient industries into military-specification contracting and thereby dull their commercial instincts. See, for instance, Jay Stowsky, *Beating Our Plowshares into Double-Edged Swords: The Impact of Pentagon Policies on the Commercialization of Advanced Technologies* (BRIE Working Paper #17, April 1986). The *Economist* (6 August 1988, 52) has also observed that European companies' reliance on defense electronics particularly in Britain has rightly been blamed for much of their poor record. Guaranteed defense contracts made companies lazy in other electronics sectors.

[110]Comments of Mary Shaw, an engineer who served on the Defense Science Board's Task Force on Defense Software, as quoted and paraphrased by *Electronics,* 4 February 1988, 128.

[111]Office of the Under Secretary of Defense for Acquisition, *Report of the Defense Science Board 1987 Summer Study on Technology Base Management* (Washington, D.C.: GPO, 1987), 2.

[112]DOD has made a promising start on reforming its chip acquisition by qualifying the entire production line at once, and, via Military Standard 35835, seeking to eliminate part-by-part qualification, destructive testing, and full-scale audits of plant records. DOD is actively marketing its Qualified Manufacturing Line (QML) designation to the computer and automotive industries. "Ultimately," says RADC's Bob Thomas, "we would like to see both military and commercial chips produced on the same line." See *Electronics,* June 1989, 62.

[113]*Electronics,* 28 April 1988, 149.

[114]*IEEE Spectrum,* November 1988, 57.

[115]*Electronics,* 14 April 1988, 32.

[116]As reported in *Defense News,* 6 March 1989, 3.

[117]*Electronics,* November 1988, 73.

[118]*Economist,* 24 September 1988, 116. From *Business Week,* 30 January 1989, 64, comes a similar description of how each country views the shape-memory market, and a warning: "That's the secret of Japanese success in business after business. Reduce the cost of new technology enough for a simple low-price product and you can always move up into higher-margin markets and undercut any competitors who don't have a foothold in some volume business."

[119]*Economist,* 19 November 1988, 98.

[120]*Byte,* March 1989, 12.

[121]Quoting Dr. Whitmire of Texas Instruments, in *Electronics,* June 1988, 65.

[122]*Electronics,* 4 March 1988, 80.

[123] Dorothy Robyn, W. Wendell Fletcher, and John A. Alic, "Bringing Superconductivity to Market," *Issues in Science and Technology* (Winter 1988-1989): 40.

[124] According to Gene Strull, vice president of Westinghouse's Defense Electronics Center, the average time between conception and fielding of a major weapons system is 12 to 14 years. See *Electronics*, June 1989, 98.

[125] *Electronics*, 18 February 1988, 108, for VHSIC. *Electronics*, 21 January 1988, 83, for MIMIC.

[126] *Economist*, 4 March 1989, 66.

[127] Roland W. Schmitt and Ralph E. Gomorty, "Competition from Japan," *MIT Report*, December 1988-January 1989, 3 (as quoted in Dertouzos, *Made in America*, 75) said, "The Japanese company gets the product out fast, finds out what is wrong with it, and rapidly adjusts; this differs from the U.S. method of having a long development cycle aimed at a carefully researched market that may, in fact, not be there."

[128] *Electronics*, 4 March 1988, 80.

[129] Alan M. Wolsky, et al., 66. "The New Superconductors."

[130] See the *Business Week* article of 8 May 1989, 142-150, as well as the *Economist* article, "Factory of the Future," a survey in its 30 May 1989 issue.

[131] *Economist*, 6 August 1988, 25.

[132] *Economist*, 20 February 1988, 23.

[133] *Economist*, 9 January 1988, 18.

[134] *Business Week*, 14 March 1983, 110. Comments were also echoed in conversation with author on FSX on 8 June 1987.

[135] *Defense News*, 1987.

[136] *Business Week*, 14 March 1983, 110.

[137] As an article on health care costs in *Business Week*, 6 February 1989, 74, in fact does.

[138] *Economist*, 28 January 1989, 46. They were referring, in this quote, to the Soviets, but the lesson applies here as well.

[139] *Economist*, 19 November 1988, 75.

[140] *Economist*, 15 October 1988, 80.

[141] *Electronics*, April 1989, 42.

[142] The following is a sampling of standards and the industries they influence:

—Manufacturing Automation Protocols for computer-integrated manufacturing and Technical and Office Protocols for similar networking in an office environment (often referred to jointly as MAP/TOP) (*Metalworking News*, 4 January 1988, 1).

—UNIX, for computers (especially for departmental and technical workstations).

—ISDN (integrated services digital services), for telephone systems.

—IGES (integrated graphics exchange standard) and PDES (product data exchange standard), for computer-aided design (*Metalworking News*, 4 April 1988, 17).

—PHIGS and Renderman for three-dimensional graphics (*Electronics*, July 1988, 105).

—Telerobotic Servicer programs for robotics (*Metalworking News*, 25 April 1988, 10) and Robot Simulation for simulation (*Electronics*, February 1989, 39).

—VHDL (very high description language) for chip descriptions (*IEEE Test and Design*, April 1986, 10-65).

—CAN and SAE's J1850 for high- and medium-speed automobile electronics multiplexing (*Electronics*, July 1988, 54).

—ATE standards for test equipment (*Electronics*, 16 April 1987, 57).

—FIDDS (fiber-optic distributed data system) for fiber-optics (*Electronics*, 26 May 1988, 99).

—FANUC's machine-control software for machine tools.

[143] From *Business Week*, 21 December 1987, page 108. Michael Hareng, Thomson's scientific director, argues that the Japanese want to introduce a world standard that belongs to them and gives them an enormous industrial advantage.

[144] *Business Week*, 28 September 1987, 70F, asserted, "The ultimate goal in smart buildings, to plug a PC into a wall socket and link an office worker to colleagues across the aisle or around the world will not be reached until standards for data communication and software become widely accepted. That's likely to occur sooner in Japan, where suppliers are working toward such standards.

[145] Dertouzos, in *Made in America*, 103, said, "Lack of standardized tests and marking systems have hindered progress in user-supplier relations. Although the auto firms agreed on the need for machine-readable bar codes for inventory, they could not agree on one standard."

[146] Dertouzos, in *Made in America*, 107, said, "Computer networking is another area where American companies have had difficulty cooperating. The need here is to establish common communications standards. Instead, each company tries to have its own solutions accepted as a national standard, with the result that U.S. standards organizations are compelled to accept a large number of such 'standards.' In Europe, by contrast, the centralized postal, telephone, and telegraph authorities have already agreed on data

communication protocols not only for each country but also among several EEC countries.''

[147] See the *Wall Street Journal,* 2 June 1989, B1.

[148] The *Wall Street Journal,* 1 June 1989, A26, asserted, "The House [Foreign Affairs international economic policy] subcommittee in its report, warned that U.S. producers of telecommunications equipment, auto parts, and medical devices could lose European sales if they aren't informed quickly of changes in product standards.''

[149] *Business Week,* 29 August 1983, 69.

[150] *Economist,* 9 July 1988, 63.

[151] *Economist,* 1 July 1989, 53.

[152] *Washington Post,* 23 March 1989, E-5.

[153] *Electronics,* November 1988, 176.

[154] Quoting a Stanford Research Institute report in *Electronics,* 4 August 1987, 98.

[155] *Electronics,* 3 October 1987, 36.

[156] A good early article on the industry may be found in *Business Week,* 9 December 1985, 90. See also *Electronics,* December 1988, 39. Players include Planar Systems (EL, see *Electronics,* 28 April 1988, 25); Photonic Technology (plasma, see *Electronics,* 14 April 1988, 26); Alphasil (LCD, see *Electronics,* 3 October 1987, 90); and Ovonic Imaging Systems (LCD, see *Electronics,* December 1988, 39).

[157] *Ibid.*

[158] Such as Ashton-Tate, Lotus, Microsoft, and Reuters, as noted in *Electronics,* 26 May 1986, 64.

[159] *Electronics,* August 1988, 52, 73, and 123.

[160] From "Survey on the Motor Industry,'' *Economist,* 15 October 1988, 22, which stated, "Components and materials represent the biggest part of the ex-factory cost of a car, often as much as 50 to 60 percent. This compares with about 20 percent for direct labor costs and the remainder for other overheads.''

Note: An ex-factory cost, by definition, includes no distribution.

[161] Selected local-content percentages

Facility	From	(when)	To	(when)
Subaru	50	now	60	soon
Nissan	40	originally	50	now
Toyota-GM	60	now	70	by 1991
Ford-Mazda	50	now	75	by 1991
Mitsubishi	N/A		60	eventually
Toyota (KY)	N/A		70	by 1991

Source: *Metalworking News,* 4 January 1988, 28. See also General Accounting Office, *Foreign Investment: Growing Japanese*

Presence in the U.S. Auto Industry, GAO/NSIAD-88-111 (Washington, D.C.: GPO, 1988).

[162] *Economist*, 19 March 1988, 75.

[163] *Business Week*, 4 June 1984, 104.

[164] Venture Development (Natick, Massachusetts) estimates that Asian sources have invested over $600 million in 120 small and mid-sized American firms over the past 3 years. Notable deals include Canon's 17-percent stake investment in NeXT, Kubuta's 44-percent stake in Ardent, and TDK's purchase of Silicon Systems (from *Electronics*, August 1989, 44). Major deals include Nippon Mining's $1.1 billion dollar purchase of Gould, and Hitachi's 80-percent stake in National Advanced Systems. *Business Week*, 26 June 1989, 117, stated, "[L]esser start-ups have been forced to seek Japanese help in manufacturing and development as well. And in the process they wound up transferring their technology."

[165] Overseas investors financed two notable GaAs firms started by Bell Labs expatriates. Mistui financed Gain Electronics, and Siemens did the same for Microwave Semiconductor. Both have since fizzled, a common result when small start-ups are bought by large hierarchical corporations (see *Electronics*, July 1989, 18, 102).

[166] *Economist*, 26 November 1988, 73.

[167] Kennichi Ohmae, *Global Logic*, 153.

[168] *Business Week*, 19 September 1988, 148.

[169] *Business Week*, 19 February 1988, 71.

[170] *Ibid.*, 90.

[171] *Economist*, 30 January 1988, 51. From the "Survey of Civil Aerospace," *Economist*, 3 September 1988, 6, which said, "It is difficult to detect the true nationality of some models. The Fokker 100 jet, for instance, is more British than Dutch; Britain's Dowty builds the undercarriage, Rolls-Royce supplies the engines and Short Brothers in Northern Ireland makes the wings. Similarly the British Aerospace 146 regional jet airliner is more American than British."

[172] Ray Vernon, "A Strategy for International Trade," *Issues in Science and Technology*, Winter 1988, 86-91. He argues that "industrial policy" would not work in the United States. It would be a waste of Government resources to favor companies that could, by virtue of their multinationalization, shift assets overseas.

[173] Compare this with the attitude of France's Industry Minister, Roger Fauroux, who believes that France needs global companies that rank in the top three in world competition. In pursuit of that aim he seeks to prevent raiders from picking off France's top companies. *Business Week*, 13 March 1989, 64.

[174]*Economist*, 16 April 1988, 82. It helps that Japanese automakers turn over only 30 percent of the car's value between models, versus 80 percent for American firms.

[175]When American firms introduced the next generation of computer memories, each new generation took 2.8 years; when the Japanese took over, each new generation took 2.3 years. See Figure 7.2 in Borrus, *Competing for Control*, 176. The cited source is Robertson, Coleman and Stephens, and Toshiba data. Now that the Japanese have collectively monopolized the market, the distance between generations may stretch out again. Every new generation is a fourfold increase in capacity.

[176]*Economist*, 9 January 1989, 59, stated, "Mr. Ron Napier of Salomon Brothers calculates that $1M worth of new Japanese foreign direct investment raises Japan's machinery exports by $436K."

[177]*Metalworking News*, 21 March 1988, 3.

[178]*Business Week*, 16 June 1986, 96H.

[179]This claim is supported in informal conversations with IBM officials in their chip-making subsidiary, as well as comments made by Xerox executives, quoted in Gary Jacobson and John Hillkirk, *Xerox: American Samurai* (New York: Macmillan, 1986).

[180]*Economist*, 12 March 1988, 66.

[181]Professor Jeffrey Frey, of the University of Maryland, observed that with 20 giant Japanese companies diving into superconductivity, so much momentum has been built that MITI simply was not needed. *Business Week*, 14 March 1988, 58.

[182]The figure is closer to 8 percent now. See *Economist*, 24 June 1989, 63.

[183]An index, developed at MITI's behest by Noritake Kohbayashi of Keio University. 5.0 means the most internationalized management structure. See *Economist*, 7 December 1985 survey on Japan, 29-30.

[184]*Japan Economic Survey*, February 1989, 4.

[185] *Metalworking News*, 7 December 1987, 44.

[186]*Economist*, 12 March 1988, 66.

[187]An intriguing argument from the *Economist*, 17 October 1987, said, "Britain became top manufacturer and banker in the 30 to 40 years after Waterloo, so the nineteenth century was a British one. Britain used its dominance to build an empire on the wrong belief that trade (instead of rancor) follows an imperial flag. But its lending on cheap bonds financed the right railways across the right parts of the wild Americas and it did better than would its only Victorian alternative (Bismark's Prussia) in spreading less militarism and more free trade and a usefully self-deprecatory sense of humor

around the world. Pause at this stage to make your own guesses about which features will change if the twenty-first century becomes considerably Japanese, as the twentieth century has been mainly American."

[188] Samuel Huntington, "The U.S.—Decline or Renewal?" *Foreign Affairs* (Winter 1988-1989): 76-96. Quote from p. 91.

[189] Felix Rohatyn, "America's Economic Dependence," *Foreign Affairs* (Spring 1989): 53-65. Quote from p. 59.

[190] *Economist*, 1 July 1989, 14.

[191] See also "Japan Builds a New Power Base: Its Emerging Clout in East Asia Could Come at America's Expense," *Business Week*, 10 April 1989, 42, and response by Jusuf Wanandi in *Japan Economic Survey* (May 1989): 6ff.

[192] *Economist*, 17 September 1988, 35.

[193] Although the quote is from R. Taggert Murphy, "Power Without Purpose: The Crisis of Japan's Global Financial Dominance," *Harvard Business Review* 2: 1989, 75, the observation is ubiquitous.

ABBREVIATIONS

AI	artificial intelligence
ASIC	application-specific integrated circuits
CRT	cathode-ray tube
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DRAM	dynamic random-access memory
EEC	European Economic Community
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FDA	Food and Drug Administration
FSX	fighter-experimental
GaAs	gallium arsenide
GNP	gross national product
GSA	General Services Administration
HDTV	high-definition television
HEMT	high-electron-mobility transistor
IC	integrated circuit
ISDN	Integrated Systems Digital Network
JVC	Japanese Victor Corporation
LCD	liquid-crystal display
MHI	Mitsubishi Heavy Industries, Inc.
MIT	Massachusetts Institute of Technology
MITI	Ministry of International Trade and Industry
NATO	North Atlantic Treaty Organization
NDU	National Defense University
NEC	Nippon Electric Corporation
NIC	newly industrialized country
NTT	Nippon Telephone and Telegraph
OECD	Organization for Economic Cooperation and Development
OS/2	Operating System/2
OSHA	Occupational Health and Safety Administration
OTA	Office of Technology Assessment
PGM	precision guided munition
R&D	research and development
RAM	rolling airframe missile
SDI	Strategic Defense Initiative
SIC	Standard Industrial Classification
SQUID	special quantum interference device
TI	Texas Instruments

TRON	the real-time operating nucleus
VAP	value-added partnership
VCR	video-cassette recorder
VHS	video home system
VHSIC	very high-speed integrated circuit
VLSI	very large-scale integration

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